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ORIGINAL ARTICLES.

I.—Cretaceous Mollusca from New Zealand.

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(*Concluded from the July Number, p. 305.*)

(PLATE XXI.)

Aplustrum (?) Selwynensis, sp. nov. (Pl. XXI, Figs. 1–3.)

Shell oval in shape, very thin, consisting of six whorls, the last one very large and inflated. In some specimens the spire is rather prominent, in others slightly depressed with rather deep sutures. The apex and protoconch when not broken off are pointed and prominent. The aperture is broad in front but narrow behind, and seems to have a faint shallow anterior channel. There is no columellar fold. The outer lip in specimens where it is preserved is sharp and very slightly flattened out and expanded anteriorly. The growth-lines are fairly prominent, and there is a tendency for faint and shallow parallel furrows to develop, especially on the anterior portion. Height about 18 mm.

This fragile shell is rather common, but often more or less crushed. *Aplustrum* is the only genus to which I can refer it, but compared with a recent specimen of *A. amplustre* it has a more prominent protoconch, which in the recent form is rather sunken and buried. The shell of the recent form also is smoother and more glossy.

Wilckens illustrates a shell (*Bulla subglobosa*)[1] viewed from the mouth side, from Quiriquina, which recalls the present form if seen in a similar position and may possibly be identical. It cannot, however, be a true *Bulla* as he says the spire is only slightly depressed, while a characteristic feature of *Bulla* is the deeply sunken and hidden spire.

I have also compared my specimens with the original illustrations of *Bulla subglobosa* and *Philine chilensis* of Philippi[2] and find that they do not resemble the figures of either, as in both of them the last whorl appears more swollen and the spire more sunken. It also recalls *Bulla glacialis*, Wilckens,[3] from the Tertiary beds of Seymour Island, Antarctica, which, as Wilckens remarks, is very like though more swollen than *B. subglobosa* of the Cretaceous of Quiriquina, but

[1] N.J. für Min., Beil. Bd. xviii, pl. xviii, fig. 11, 1904.

[2] Tert. u. quart. Versteinerungen Chiles, 1887, pl. xiii, figs. 2*a*, *b*, 4.

[3] "Die Mollusken der Antarkt. Tertiarformation": Wissensch. Ergebn. der Schwed. Südpolar Exped., p. 29, pl. i, figs. 36*a–c*, 1911.

none of the figures show the elevated protoconch of the New Zealand shell.

Locality.—Selwyn Rapids, rather common in one piece of rock.

Holcodiscus (Kossmaticeras) gemmatus, Hupé. (Pl. XXI, Fig. 6.)

Ammonites gemmatus, Hupé, Gay's Hist. Chile, 8, 35, pl. i, fig. 3, 1854.
Holcodiscus gemmatus, Hupé, Steinmann, "Ceph. d. Quiriquina Schichten": N.J. für Min., Beil. Bd. x, p. 68, pl. vi, figs. 1*a*, *b*, 2*a*, *b*, 1895.
Wilckens, "Revision d. Fauna der Quiriquina Schichten": N.J. für Min., Beil. Bd. xviii, p. 187, 1904.
Kilian et Reboul, "Les Céphalopodes Néocrétacés des îles Seymour et Snow Hill": Wissensch. Ergebnisse der Schwed. Sudpolar Exped., Stockholm, 1909.

A fragment of an Ammonite was obtained at Selwyn Rapids, but owing to the blasting operation only about a third of the sutured portion of the last whorl could be found. It has been partly crushed and the sutures cannot be made out without destroying the specimen, but the outer shell with its ornamentation is very well preserved. The last whorl embraces about half the previous one and the umbilical slope is steep, almost vertical. The venter is rounded and the ribs cross it with great regularity. They are equally spaced on the venter, but are less regular on the sides. Only about half the number of ribs that cross the venter reach the umbilical shoulder, approximately every alternate rib disappears rather less than halfway from the venter to the umbilical slope. Of those that continue two or occasionally three unite at the umbilical shoulder to form a series of rather closely spaced sharp oval nodes whose apices are directed backwards. The ribs are slightly sinuous on the sides.

This fragment agrees so closely in external ornamentation with the examples figured from Quiriquina and Antarctica that there can be no doubt of its identity. It is common in the Upper Cretaceous of Seymour Island, but has not been found in South Patagonia, where, however, the three Indian species, *H. Theobaldinus*, *Bhawani*, and *Æmilianus*, all of Stoliczka, occur. In addition to the three forms just mentioned the Aryalur Beds of the Indian Senonian yield the closely allied species, *H. Madrasinus*, Stol., *Kandi*, Stol., and *Kalika*, Stol.

Locality.—Selwyn Rapids, one specimen.

Belemnites sp. (Pl. XXI, Fig. 9.)

A single Belemnite fragment was collected at Selwyn Rapids. It measures 24 mm. in length and forms the terminal part of a guard, but no trace of phragmocone remains. It seems to have been rolled and is split in two pieces longitudinally. The rock adheres so closely to the outer surface that very little of this is visible. In size and shape it resembles very closely some more or less rolled fragments of Belemnite guards that occur at Brighton, 12 miles south of Dunedin, in a hard pebbly shell bed resting almost directly on the coal, which rests in turn on the eroded schists. Hector called this fossil *Belemnites Lindsayi*. The bed was classified as Tertiary by the earlier New Zealand geologists, but this correlation will probably have to be revised, and Professor Marshall is inclined to

correlate it with the Wangaloa Bed. The other fossils in it seem to be very poorly preserved. Professor Marshall sent some specimens of these Belemnites to Wilckens, who submitted them to other specialists. Their opinion was that they were too much rolled for accurate identification, but were certainly true Belemnites.

The present fragment, though clearly a true Belemnite, is too poorly preserved for further determination, but its occurrence among the fauna of Selwyn Rapids is significant. For comparison I illustrate two specimens of the Brighton Belemnite (Pl. XXI, Figs. 7, 8) which were kindly given to me by Professor Marshall.

Correlation.

The limited number of fourteen fossils under examination in the present paper indicates the absolute agreement of the Cretaceous of New Zealand with that of the rest of the Indo-Pacific region.

The *Conchothyra parasitica* beds at Selwyn Rapids and the Waimakariri Gorge are clearly of the same age and correspond very closely with the *Pugnellus* and *Trigonia Hanetiana* beds of Quiriquina in Chili and the *Pugnellus* and *Aporrhais gregaria* beds of South Patagonia. There can be no doubt that the *Pugnellus* bed in the Waipara Gorge is also of approximately, if not of exactly similar, age.

Steinmann[1] says, "The Quiriquina Beds of South Chili are of the same age as the upper division of the European Senonian, and definite faunal relations exist between them." Wilckens[2] regards the South Patagonian higher Cretaceous beds as the equivalent or at least the analogue of the Quiriquina of Chili.

It is thus a matter of interest to find in the same bed at Selwyn Rapids in New Zealand species such as *Aporrhais gregaria*, which occur in South Patagonia but not at Quiriquina, and *Holcodiscus* (*Kossmaticeras*) *gemmatus*, which is found at Quiriquina but not in South Patagonia, but which recurs at Seymour Island off the coast of Graham Land in Antarctica.

The reported identification by Mr. Woods of a Gault fauna in New Zealand has already been mentioned. It may turn out that beds closely resembling those with *Inoceramus Steinmanni* in South Patagonia will also be found. It remains to be seen when Professor Marshall's work on the Wangaloa fossils is published whether this fauna, which should apparently be of Maestrichtian age, finds any close parallel in South America or elsewhere.

I found no Tertiary species among the Upper Senonian fossils of New Zealand which I examined. Some Tertiary forms might be expected to occur in the Wangaloa Beds, but for details of these I await Professor Marshall's report.

The number of Upper Senonian forms common to New Zealand, South America, and Graham Land points to a much closer connexion between these regions than obtains at the present day, and indicates a land mass or a group of islands in the South Pacific joining New Zealand to South America previous to the Tertiary uplift of New

[1] N.J. für Min., Beil. Bd. x, p. 27, 1895.
[2] Bericht der Naturgesell. Freiburg, 1907, Bd. xv, p. 63.

NAME.	LOCALITY.	HORIZON.	AFFINITIES.
Trigonia cf. *Hanetiana*, d'Orb. (Pl. XXI, Fig. 5).	Waimakariri Gorge.	Upper Senonian.	Hector's *Trigonia sulcata*, apparently identical with *T. Hanetiana*, common at Quiriquina in Chili.
Dentalium sp. (Pl. XXI, Fig. 10).	Selwyn Rapids.	,, ,,	Resembles *D. Chilensis*, d'Orb., of Quiriquina.
Natica (*Euspira*) *variabilis*, Moore (Pl. XIX, Figs. 8–10).	,, ,,	,, ,,	Occurs in Lower and Upper Cretaceous of Australia, and is found in the opal beds of New South Wales.
Chrysostoma Selwynensis, sp.nov. (Pl. XXI, Figs. 4*a*, *b*).	,, ,,	,, ,,	Apparently new form.
Turritella sp. (Pl. XIX, Fig. 11).	,, ,,	,, ,,	Too imperfect to determine specifically.
Neritopsis (?) *Speighti*, sp. nov. (Pl. XIX, Figs. 12–15).	,, ,,	,, ,,	Recalls *Vanikoro Kiliani*, Wilckens, of the Upper Cretaceous of Antarctica, but is much larger.
Conchothyra parasitica, McCoy (Pl. XX, Figs. 4, 5).	Selwyn Rapids and Waimakariri Gorge.	,, ,,	Apparently peculiar to New Zealand.
Pugnellus Marshalli, sp. nov. (Pl. XIX, Figs. 1–4).	Selwyn Rapids.	,, ,,	,, ,, ,, ,,
P. Waiparensis, sp.nov. (Pl. XX, Figs. 1*a*, *b*).	Waipara Gorge.	,, ,,	Resembles *Pugnellus Hauthali*, Wilckens, of the Upper Cretaceous of South Patagonia.
P. australis, Marshall (Pl. XX, Figs. 2*a*, *b*, 3*a*, *b*).	Wangaloa.	Maestrichtian (?).	Apparently confined to the Wangaloa Beds of New Zealand.
Alaria Suteri, sp. nov. (Pl. XIX, Fig. 5).	Selwyn Rapids.	Upper Senonian.	Apparently a new form.
Aporrhais gregaria, Wilckens (Pl. XIX, Figs. 6–7).	,, ,,	,, ,,	Occurs in Upper Cretaceous of South Patagonia, but not at Quiriquina.
Aplustrum (?) *Selwynensis* (Pl. XXI, Figs. 1–3).	,, ,,	,, ,,	Recalls *Bulla subglobosa*, Philippi, of the Upper Cretaceous of Quiriquina, and *B. glacialis*, Wilckens, of the Tertiary of Antarctica.
Holcodiscus (*Kossmaticeras*) *gemmatus*, Hupé (Pl. XXI, Fig. 6).	,, ,,	,, ,,	Occurs at Quiriquina and Seymour Island in Antarctica, but not in South Patagonia.
Belemnites sp. (Pl. XXI, Figs. 7–9).	,, ,,	,, ,,	Resembles *Belemnites Lindsayi*, Hector, from Brighton, 12 miles south of Dunedin.

Zealand or of the South American Cordillera. This connexion probably included a portion of the present continent of Antarctica.

In contrast to the large number of forms common to South America and Seymour Island the slightness of the connexion with the Australian Upper Cretaceous is shown by the presence of only one Australian Gasteropod, *Natica* (*Euspira*) *variabilis*. This seems to be the sole connecting link in the molluscan fauna with the much nearer continent of Australia. Eight species out of fifteen seem to be confined to New Zealand. The Upper Cretaceous of New Caledonia is yet very little known, but according to Haug *Kossmaticeras Bhavani*, of the Aryalour group of India, has been found, and so it is possible that some forms at present thought to be restricted to New Zealand may occur there.

I am indebted to Dr. A. Smith Woodward for the following notes on some fish-scales discovered with the Cretaceous fossils described above:—

"The largest scales are evidently referable to Berycoid fishes. They are much deeper than broad, with a relatively small and somewhat thickened exposed sector. The best-preserved specimen is shown of the natural size in Pl. XXI, Fig. 11*a*, with a portion enlarged four times in Fig. 11*b*. Its extensive covered area is marked by the very fine and numerous concentric lines of growth, which tend to subdivide into minute granules near the edge of the exposed area (Fig. 11*b*). It is also slightly impressed with a few grooves which radiate forwards and produce a waviness in the concentric lines of growth where they cross them. The small thickened exposed area of the scale is ornamented with comparatively large and rounded radiating ridges, which are feebly marked for the greater part of their extent, but become raised into irregular elongated tubercles near the anterior overlapped margin (Fig. 11*b*). The free posterior border of the scale is somewhat obscured by matrix, but does not appear to have been sharply serrated. Part of an apparently similar scale is clearly only wavy, not serrated, at the posterior border.

"A smaller scale, more incompletely preserved, is shown of three-halves the natural size in Pl. XXI, Fig. 12*a*, with a fragment of its exposed area enlarged four times in Fig. 12*b*. The tissue is a little disintegrated, but it displays the very fine concentric lines of growth and the few radiating grooves in its covered area; while the hinder border of its comparatively smooth exposed area bears coarse sharp serrations and pectinations impressed again by the fine concentric lines of growth. The imprint of the inner face of the scale seems to show traces of the irregular tuberculation which has already been noticed on the inner face of the scales of the Berycoid *Hoplopteryx*.

"Another well-preserved fish-scale, shown of twice the natural size in Pl. XXI, Fig. 13, may be regarded as belonging to an Elopine Clupeoid. Its large covered area, displaying extremely fine concentric lines of growth, is crossed by numerous sharp radiating grooves which have become clefts by crushing. Its denser exposed area is nearly smooth, but bears faint traces of a few radiating lines.

Usually in the scales of Elopines the radiating ornament on the exposed area is more conspicuous than in this case; but similarly feeble markings are observable on a scale in the type-specimen of *Thrissopater megalops* from the English Chalk.

"The fossil fish-scales from New Zealand thus belong to groups of teleostean fishes which are abundant in Cretaceous formations in other parts of the world."

EXPLANATION OF PLATE XXI.

1-3*b*. *Aplustrum Selwynensis*, sp. nov. Selwyn Rapids. Fig. 3*a* × 1½ nat. size; Fig. 3*b* × 5 nat. size.
4*a*, *b*. *Chrysostoma Selwynensis*, sp. nov. Selwyn Rapids. × 3 nat. size.
5. *Trigonia* cf. *Hanetiana*, d'Orb. Waimakariri Gorge.
6. *Holcodiscus* (*Kossmaticeras*) *gemmatus*, Hupé. Selwyn Rapids.
7, 8*b*. *Belemnites* sp. Brighton, south of Dunedin. Maestrichtian (?). Fig. 8*b* × 1½ nat. size.
9. *Belemnites* sp. Selwyn Rapids. × 1½ nat. size.
10. *Dentalium* sp. Selwyn Rapids. × 2 nat. size.
11. Berycoid fish-scale, outer view, natural size (11*a*), with portion of adjoining covered and exposed areas enlarged four times (11*b*).
12. Fragments of Berycoid fish-scale, outer view, preserved on inner impression of same, three-halves natural size (12*a*) with portion of exposed area enlarged four times (12*b*).
13. Elopine fish-scale, outer view, twice natural size.

[Plates XIX and XX appeared in the July Number.]

On Pl. XX, Figs. 1*a* and *b* and 3*a* and *b* should be transposed, an unfortunate error having occurred in the numbering. The specimen figured at the left-hand top corner really represents *Pugnellus Waiparensis*, sp. nov., and that at the right-hand top corner represents the normal form of *Pugnellus australis*, Marshall, from Wangaloa.

NOTE.—In some of the copies the following correction is needed at the foot of Plate XIX, which appeared in the July Number GEOL. MAG., next p. 304: for CRET EOUS *read* CRETACEOUS (two letters AC having accidentally fallen out).—ED. GEOL. MAG.

II.—MORPHOLOGICAL STUDIES ON THE ECHINOIDEA HOLECTYPOIDA AND THEIR ALLIES.

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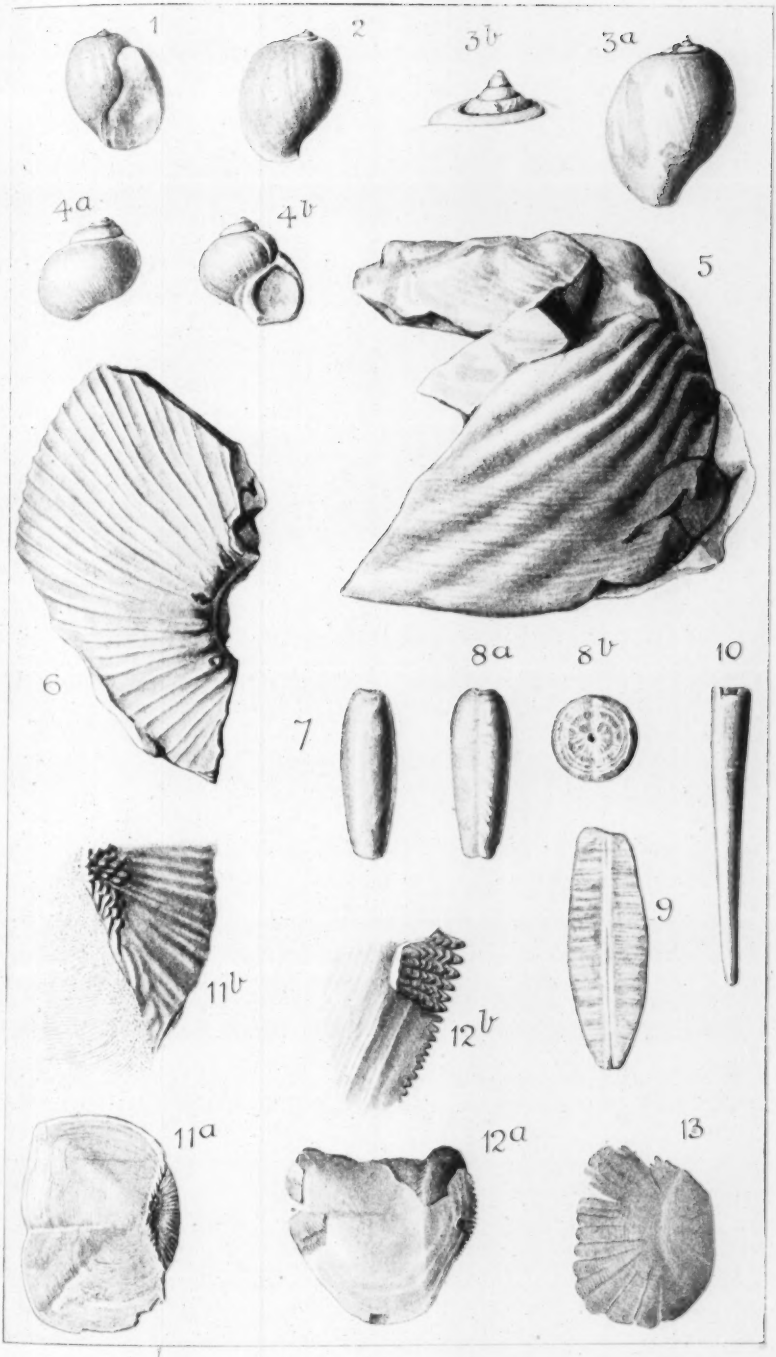
IV. THE PERIGNATHIC GIRDLE OF THE PYGASTERIDÆ.

(WITH FIVE TEXT-FIGURES.)

1. INTRODUCTION.

THE examination of the internal structures of Jurassic fossils is attended with considerable technical difficulties. Even in cases where the surrounding matrix is sufficiently friable for the development of the external surface, the infilling material is usually either thoroughly indurated or irregularly nodular in texture. Internal moulds may be readily procured, both by natural weathering and artificial processes. But such preparations, though adequate for the investigation of shallow impressions such as the muscle-scars of Pelecypoda, are of uncertain service for the study of structures with



G. M. Woodward, del. Bale & Sons, imp.

UPPER CRETACEOUS FOSSILS, NEW ZEALAND.

high relief. Specimens of *Pygaster semisulcatus* (olim "*P. umbrella*") are frequently found in the Corallian of Berkshire in the state of decorticated moulds, and in such examples the presence of strong perignathic prominences is indicated by deep pits on the adradial sides of the branchial incisions. But attempts to reproduce these perignathic structures by gutta-percha casts have hitherto proved unsuccessful. The pits are so deep that it is almost impossible to ensure their perfect emptiness; and they are internally expanded and curved. For these reasons our knowledge of the perignathic girdle of the Jurassic Holectypoida has up to the present been practically confined to a realization that such a structure existed in robust development. Lovén ("Recent Form of the Echinoconidæ" and "Echinologica") ascertained something of its character by means of sections, but was able to examine the more prominent features only.

After many failures, I have succeeded in exposing the girdle, with varying completeness, in two fully grown specimens of *Plesiechinus ornatus* (olim *Pygaster semisulcatus*) from the Aalenian (Pea Grit) of Leckhampton. In many examples there is a cylinder of fairly yielding matrix connecting the apertures of the periproct and peristome, while the limestone wholly sheltered by the test is in a very refractory state. In the two specimens on which this paper is based, the soft plug, though containing many pisolite grains, was slightly greater in diameter than the peristome; and so it was possible, by slicing off the adapical surface, to expose all of the perignathic structures in one instance and the adoral parts of them in the other. The more completely developed specimen is now in the collection of the Geological Department, University College, Reading, registered number 924.

The structures shown in the prepared specimens have a special interest in view of the primitive qualities of the genus *Plesiechinus*. In the present paper a brief comparison is made between the perignathic girdle of the Pygasteridæ and that of the simpler types of the Diademoida (Centrechinoida). For the purpose of this comparison I have used Jackson's summary and diagrams given in his "Phylogeny of the Echini", pp. 189–195, reinforced by a few observations of my own. A detailed comparison with the later Holectypoida and the Clypeastroida (in which, thanks to the work of Lovén and Duncan, the girdle is already well known) is postponed to a later paper partly prepared.

2. The Perignathic Girdle of *Plesiechinus ornatus*.

(a) *The relations of the basi-coronal plates.* (See p. 344, Fig. 1.)

The peristome of *Plesiechinus* (and of all Jurassic Pygasteridæ) is approximately circular in outline, but the circumference is strongly "festooned" by profound branchial incisions. These incisions, as is usual in Ectobranchiate Echinoidea, involve those parts of the interambulacral margin that are contiguous to the ambulacra. As may be seen by reference to Fig. 1, the branchial incisions are not equidistant, the measurement across an ambulacrum being greater than that across an interambulacrum. The actual

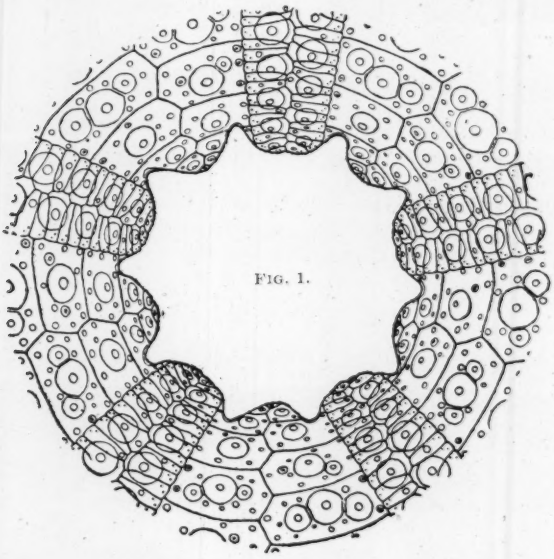


FIG. 1.

FIG. 3.

FIG. 4.

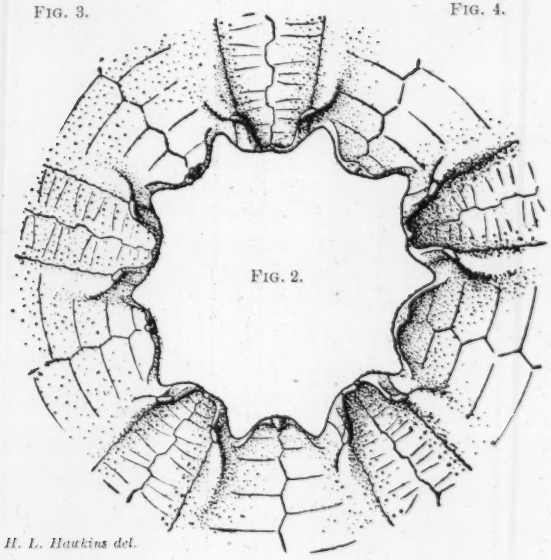


FIG. 2.

H. L. Hawkins del.

FIG. 1. Peristome of *P. ornatus*, external view. × c. 3.
,, 2. ,, ,, ,, internal view. × c. 3. Coll. Univ. Coll., Reading, Geol. Dept., No. 924. The figure is partly restored, several of the processes having been broken during development.
,, 3. Oral aspect of a pair of processes. × c. 6.
,, 4. ,, ,, an interradial "ridge". × c. 12.

amount of peristomial circumference (reduced to a simple circle) built up by the two areas is approximately the same, but the interambulacral portion is entrenched upon by the branchial incisions. The ambulacra present a semi-elliptical margin to the peristome, while that of the interambulacra is more nearly semi-circular. The ambulacral pores, which are not crowded nor much displaced from their direct line, pass down near to the adradial sides of the branchial incisions, and curve round with the margin of their areas.

The primordial, unpaired plate of the interambulacrum is preserved as a small, triangular ossicle. The interradial sides of the branchial incisions are formed of the edges of two or three paired interambulacral plates, and the single plate occupies only the apex of the semicircular margin of the area. Lovén ("Recent Form of the Echinoconidæ") recognized the persistence of the unpaired plate in *Plesiechinus*.[1] It is interesting as showing that this typically Spatango-Clypeastroid feature was developed at the very outset of "Irregularity".

A slight groove extends along the border of the interambulacrum from the branchial incision to nearly half-way across the adoral surface. It is marked by the absence of large ornament, the presence of guttate granules, and the development of small pits on the transverse sutures. As will be seen later, this specialized region coincides in position with a definite internal structure.

The adoral surface of *Plesiechinus* is slightly concave, but at a region nearly coincident with the position of the apices of the branchial incisions a decided, though short-lived, invagination sets in. Thus the basi-coronal plates at the peristomial border are almost vertically disposed. All the plates of the adoral surface are surprisingly thin, even in large and gerontic individuals where the adapical plates are massive.

(b) *The ambulacral processes.* (See p. 344, Figs. 2, 3.)

These structures have been partially described by Lovén (loc. cit.). They present an anomalous appearance when partly cleared of matrix. They seem to be massive, ridge-like prominences, situated obliquely to the radius across the actual adradial suture, and to possess an escarpment-like adoral end, with a steep "dip-slope" passing adambitally and soon merging into the general inner surface of the test. They obviously spring from the ambulacrum near the peristomial margin, but are quite as clearly based upon the interambulacral plates for the greater part of their extent. When the preparation of the specimen is complete the explanation of this peculiar anomaly is seen. The actual process is a slender, lath-like projection rising from the ambulacrum near the adradial margin and

[1] Lovén (Études, pl. xiv, figs. 124 and 125) has shown the primordial interambulacral also in *Holectypus* and *Discoides*. It is almost unnecessary, if not presumptuous, to confirm the accuracy of Lovén's observations on Echinoid structures; but in the case of his fig. 124 (*Holectypus*) I have a prepared specimen which agrees with his drawing in even the minutest particulars.

leaning outwards towards the interambulacrum, though practically vertical when viewed from the branchial incision. The process is narrow at the base, and a little broader at the summit, where it is capped by an ovoid expansion which overhangs its sides. It leans against, and is visibly sutured to, a much more massive buttress which is almost wholly interambulacral in position, and constitutes the "dip-slope" of the whole structure. Lovén ("Echinologica") seems to have ascribed this buttress to the ambulacrum in its entirety, but this is contrary to my observations. His meaning is rather difficult to follow in the passage (loc. cit., p. 51) dealing with this structure. The buttress has a rounded crest, which overhangs, in a slight eave, the concave hollowing of its side adjacent to the branchial incision. The whole buttress, at first directed in a line continuous with that of the process, gently curves back towards the adradial suture, near to which, but on the interambulacral side, it passes until it sinks to the general level of the test. The position of this buttress is indicated externally by the specialized smooth area referred to above (section 2, a). The texture of the stereom of the buttress is different from that of the process, the former being soft and friable, while the latter is almost porcellanous. It is obvious that the buttress is no part of the perignathic girdle strictly speaking, but is merely a strengthening structure for the better support of the process, and the stiffening of the extremely thin plates in the region of the peristomial invagination.

In the more important specimen, the diameter of which is 74 mm. (the peristome being 12 mm. across), the average height of the processes, measured from the internal surface of the test at their base, is almost exactly 3 mm. The interradial buttresses extend towards the ambitus for a distance of about 8 mm. from the apices of the branchial incisions.

The ambulacral pores pass between the bases of two processes without perforating them and without being deflected from their straight course. They pierce the test very obliquely near the peristome, but otherwise show no disturbance due to the processes. I have seen no trace of a suture at the base of any of the twenty processes examined, but these lines are so faint on even recent tests that there is no reason to doubt their occurrence.

In the perradial line, just at the peristomial margin, there is a small ovoid prominence or thickening of the invaginated edge of the ambulacrum. This unpaired structure is probably not a part of the girdle, in as far as that apparatus serves as a support for the jaw-muscles. Of itself the prominence is of trifling importance, but a similar thickening of much greater relative size occurs in *Conulus*, so that its presence in *Plesiechinus* seems worth recording.

(c) *The interradial "ridges"*. (See p. 344, Text-figs. 2, 4.)

At first sight the perignathic girdle seems to be composed solely of the ambulacral processes above described, the equivalents of the ridges (Duncan) or apophyses (Jackson) being so feebly developed. There is a slight thickening of the test along the margins of the

branchial incisions, but this is presumably for the purpose of affording a safe exit for the branchiæ, and has nothing to do with the jaw-apparatus. But on careful investigation it is seen that the invaginated rim of the primordial interambulacral plate is thickened, and leads up by a concave curve to a small, rounded prominence which lies in the median interradial line. There is, in fact, a very slight ridge, extending across the projecting portion of the interambulacral margin, and culminating in a central prominence whose axis is considerably inclined from the vertical. At each side of the central knob (which is less than one-sixteenth of the height of the ambulacral processes), the "ridge" shows a slight drop, as if to render the prominence more conspicuous. A very delicate, blunt carina passes adorally from the knob to the margin of the peristome, dividing the concave slope of the ridge into two halves. As far as I have been able to determine, the adambital side of the ridge is slightly undercut, so that it overhangs the interambulacrum. In this respect, as in the development of a median carina, this feeble section of the perignathic girdle resembles that of many Diademoida. The homologies between its several parts and those of the Cretaceous Holectypoida will be discussed in the forthcoming paper to which reference has already been made.

(d) *The distribution of the lantern-muscles.* (Fig. 5.)

The lantern of *Plesiechinus* is at present unknown as regards its detailed structure. That of *Discoides* only, among the Holectypoida, has been adequately described. It is, however, quite unnecessary to argue the question of its presence or absence in the Jurassic genus. During the development of one of the girdles above described, I cut through certain delicate Echinoid ossicles which were without doubt portions of pyramids, but the refractory nature of the matrix made it impossible to see any but sectional views of them. For the purpose of reconstructing the musculature of the jaw-apparatus it is necessary and reasonable to suppose that the lantern was essentially similar to that of the Diademoida, with tendencies in the direction of that of *Discoides* and the Clypeastroida.

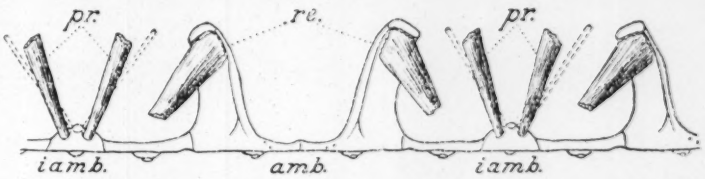


FIG. 5.—Schematic restoration of the attachment of the lantern muscles to the perignathic girdle in *Plesiechinus*. *pr.* protractors, *re.* retractors. The hypothetical radial compass muscles are indicated by double broken lines.

There can be little doubt that the retractor muscles were attached to the upper parts of the ambulacral processes, on their interradial

faces. Retractors based upon the two sides of an arched "auricle" serve hemi-pyramids belonging to two separate maxillæ, and so normally diverge. The planes of the interradial faces of the processes in *Plesiechinus* are themselves directed away from one another, so that a divergent pair of retractors could spring from them practically at right angles to the articulating surface.

The protractor muscles must have been based either upon the incipient ridges (as they would be in Diademoida), or else far back and low down on the interradial sides of the processes (after the manner of Clypeastroida). The feebleness of the interradial elements of the girdle in *Plesiechinus* would tend to suggest the latter alternative, but nevertheless I incline to believe that they had the former position. In *Discoides* and *Conulus* there is no "interradial face" to the process, which rests against, and is sutured to, a ridge-like thickening of the test of practically the same height as itself. And the two concave bays, resembling "combes" on an escarpment, that occur on the adoral surfaces of the small ridges, seem to demand an explanation which is most satisfactorily given by calling them muscle-impressions. *Plesiechinus* is far more like a Diademoid than a Clypeastroid in general characters, so that the balance of probability would place the protractors on the ridges, insignificant though they are.

The only other series of jaw-muscles that are attached to the perignathic girdle in Diademoida are the slender "radial compass muscles", which diverge from the forked ends of the compasses. They spring from the ridges, above and behind the protractors, in the Regularia Ectobranchiata. The two slight depressions on each side of the central interradial knob are extremely suggestive of sites for the attachment of these muscles. But if the depressions had this purpose their presence would imply the existence of compasses in the lantern of *Plesiechinus*. Compasses are not known in *Discoides* (though their fragile nature might well account for their non-preservation), and they are definitely absent from the Clypeastroid lantern. The existence of radial compass muscles in *Plesiechinus* must therefore be regarded as problematical. In the accompanying restoration, I have inserted them as dotted lines in the position that they would presumably have occupied if they were developed.

There is no indication of the existence of any additional retractor muscles, such as occur in the Clypeastroida, but on the other hand there is no reliable proof of their absence. The processes, apart from their supporting buttresses, are so slender that they seem unlikely to have given support to more than the single retractors.

3. The Perignathic Girdle of *Pygaster* and *Holectypus*.

As far as can be judged, there is no essential difference in the position and relative proportions of the elements of the girdle in *Pygaster semisulcatus* from that already described. I have studied the apparatus only from internal moulds of this species.

In *Holectypus hemisphæricus* and *depressus* I have succeeded in clearing the inner parts of the peristome sufficiently to reach the adoral edges of the processes, which are like those of *Plesiechinus* in

all the features shown. By means of serial sections, it has been possible to recognize that the whole girdle, in both species, is practically identical with that already described. The buttresses have similar characters in all three genera, but seem to be shorter and steeper in *Pygaster*, and less massive in *Holectypus*. In both the genera last named the plates of the adoral surface are exceedingly thin—more so proportionately than in *Plesiechinus*—so that actual development of the inner surface is a matter of great difficulty, even when the outer surface is still encased in matrix. The infilling material is generally completely indurated in *Holectypus*, and when a band of less refractory rock is found it proves to be a thin film in contact with the test along a narrow belt connecting the peristome with the periproct.

4. A COMPARISON BETWEEN THE PERIGNATHIC GIRDLE OF *PLESIECHINUS* AND THAT OF PRIMITIVE REGULAR ECHINOIDEA.

The perignathic girdle of *Plesiechinus* is definitely Diademoid (Centrechinoid) in character, and shows no affinity to the Cidaroid type. That is to say, its major elements are situated on the ambulacral plates; the interradial ridges of the Cidaroida being practically unrepresented. The interradial buttresses have evidently no homology with the Cidaroid ridge, being behind the true girdle, and having a merely mechanical function for the better support of the fragile adoral surface. They reach their fullest development in *Discoides* and the Clypeastroida. The sudden and complete transference of the "auricle" from the interambulacrum to the ambulacrum, which accompanied the change from the Cidaroida to the Diademoida, is one of the chief gaps still unbridged in the evolutional history of the Echinoidea. The process was absolutely completed in the Pygasteridæ.

The two vertical, unarched processes on the ambulacrum are in keeping with the general Jurassic character for the girdle. The Calycina, *Hemicidaris*, *Pseudodiadema*, *Stomechinus*, and even the Cretaceous *Cyphosoma* all possess "disjunct" auricles. And in all the genera except the last named the interradial portions of the girdle are very feebly developed. These features are morphogenetically neanic, or perhaps nepionic; the girdles of later Echinoids which possess elaborate structures all passing through a stage comparable with this Jurassic phase. The central knob on the ridge is a feature very constantly found in those Diademoida which have interradial developments of the girdle (e.g. *Salmacis*).

But in three important respects the Pygasterid girdle differs from that of the Diademoida. The processes are situated at the extreme interradial edges of the ambulacra, and are not perforated by the ambulacral pores. In the Diademoida the processes often spring from expanded bases which involve practically the whole width of the ambulacral columns, and are in consequence passed through by the podial pores. In *Plesiechinus* the processes are inclined away from the margin of the peristome, while in the Diademoida they rise directly from, and almost at right angles to, the margin. And lastly, the processes of

the Pygasteridæ, so far from converging across the ambulacrum, actually diverge, while Diademoid processes, even when they do not meet in an auricular arch, are always inclined towards one another.

These three points of difference are all in a sense prophetic of the subsequent perignathic changes in Holectypoida and Clypeastroida. The wide basal separation and increasing divergence of the processes suggest the future shifting of these structures to an interradial convergence as seen in *Clypeaster*, and more completely in *Echinocyamus* or *Echinarachnius*. The situation of the processes of *Plesiechinus* well back from the peristomial margin is found in a greater degree in the Clypeastroida, and implies a considerable inclination of the lantern away from its typically vertical position in Regular Echinoidea.

The interradial ridges, feeble though their development is, have strong points of resemblance with the homologous structures of *Discoides* and *Conulus*, as I hope to show in a forthcoming paper.

It thus appears that the perignathic girdle of the Pygasteridæ shows a very close correspondence with that of phylogenetically or ontogenetically young Diademoida as regards the essential disposition of its elements; but that in its details it already indicates a progressive tendency towards the Clypeastroid type of girdle. The development of the short interradial buttresses, though clearly an adaptation to the requirements of the thin invaginated peristome, represents another foreshadowing of a typically Clypeastroid feature.

III.—Some Tertiary Dykes of the Clyde Area.

By G. W. Tyrrell, A.R.C.Sc., F.G.S., Lecturer in Mineralogy and Petrology, Glasgow University.

(*Concluded from the July Number, p. 315.*)

Leidleite and Inninmorite.—Typical rocks of these groups are as yet unknown in the Clyde area. A N.N.W. dyke at Barrassie Sands, near Troon (Ayrshire), has points in common with leidleite. It shows anorthite phenocrysts in a subvariolitic groundmass of acicular felspar and augite, enveloped in a partially devitrified glassy base. A north–south dyke at the north end of Loch Fad, Bute, may perhaps be regarded as a doleritic end-variety of leidleite (see Anderson & Radley, 1916, fig. 2*b*, p. 208). A pitchstone-like dyke from the Smurig Burn in the south of Arran has all the characters of leidleite, except that it carries rather abundant granular augite, instead of acicular crystals.

Tholeiite (Brunton Type).—This type has been based by the petrographers of the Geological Survey on the so-called "augite-andesite" of the Brunton dyke, Bingfield, Northumberland, figured by Harker (1908, fig. 54, p. 203), and described and figured by Teall (1884, pp. 236–7). It is abundant among the Tertiary dykes of Mull, and two analyses of the type have recently been recorded (Geological Survey, 1914, p. 82; 1915, p. 55). In the brief notes accompanying the analyses these rocks are said to be composed respectively of "small clots of augite and acicular crystals of plagioclase, with interstitial dark-brown glass", and of "augite,

moderately basic plagioclase, magnetite, and of dark interstitial glass". Teall describes the microscopical character of the Brunton dyke as follows: "long, narrow, lath-shaped felspars, irregular crystalline grains and plates of a nearly colourless pyroxene, and a small quantity of nearly opaque interstitial matter." The rock is figured in pl. xii, fig. 6, of his paper. Judging from the figures given by Harker & Teall, and from thin sections of Brunton types from the North of England dykes in the collection of the Geological Department of Glasgow University, the felspar and augite are approximately equally developed, with perhaps a slight excess of the pyroxene, and the amount of glass is only slightly subordinate to either of the crystalline constituents. The Tynemouth dyke and several of the Ayrshire examples carry large phenocrysts of bytownite or anorthite of exactly the same characters as in cumbraite or inninmorite. Magnetite may or may not be present, and the texture is typically intersertal or tholeiitic. The type is clearly more basic than leidleite, inninmorite, or cumbraite, a fact reflected in the diminished quantity of glass. Norms calculated from the analyses of the Brunton type published by the Geological Survey show no quartz and 5 per cent of orthoclase in the 1914 analysis, and 4·2 per cent of quartz and 5·5 per cent of orthoclase in the 1915 analysis. Both rocks fall into the subrang *camptonose* (III, 5. 3. 4), showing at once that they are richer in the femic minerals than cumbraite, etc., and that there is only a negligible amount, if any, of excess silica.

a *b*

FIG. 2*a*.—Tholeiite (Brunton type), N.N.W. dyke, Stairaird, River Ayr, near Mauchline, Ayrshire. × 20. Large phenocryst of bytownite-anorthite; groundmass: grains of augite, and laths of labradorite, in base of dark glass.

,, 2*b*.—Olivine-tholeiite (Corrie type), N.N.W. dyke, Birchpoint, Corrie, Arran. × 20. Corroded phenocrysts of bytownite-anorthite; groundmass: laths of labradorite, grains of augite, olivine, and magnetite, in scanty base of dark glass.

The Ayrshire examples of the Brunton type of tholeiite may be represented by a N.N.W. dyke crossing the River Ayr near Stairaird, Mauchline. This rock (Fig. 2*a*) shows clusters of almost colourless granular augite, intermixed with diversely arranged, short felspar laths (Ab_1 An_1), all held in a black glass. The phenocrysts consist of bytownite-anorthite with a narrow rim of labradorite, exactly similar to those of cumbraite. A rough estimate of relative proportions is about 35 per cent each of the groundmass felspars and augite, 20 per cent glass, and 10 per cent of anorthite phenocrysts. A very small amount of olivine, fresh in this rock but serpentinized in the others, may be detected. On examination by a high-power objective the "black" glass turns out to be colourless, but charged with swarms of opaque black microlites. N.N.W. dykes conforming to this type, and exhibiting only minor variations in the quantitative relations of the minerals, occur in the River Ayr at Failford, near Tarbolton; in the Broadlie House Burn, near Dalry; and in the Coachford Burn, Cooperhill, Ochiltree.

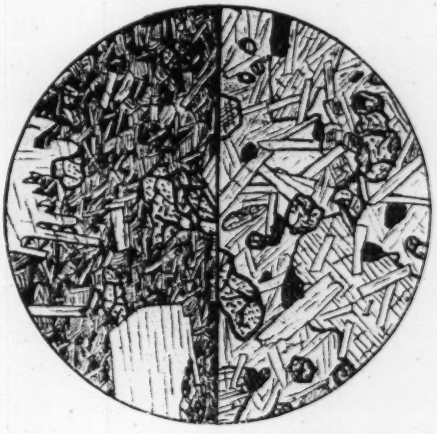
Tholeiites of the Brunton type do not appear to be common in Arran, only three examples being known in a large suite of the Tertiary dykes. These dykes occur in the South Locherim Burn, Corrie; at 1,538 feet on the Saddle, between Glen Rosa and Glen Sannox; and on the shore near Largiemeanoch, Whiting Bay. Likewise Dr. W. R. Smellie's slides of the Tertiary dykes of Bute show only three examples belonging to the Brunton type, a dyke at the south end of Loch Fad; in the quarry behind the Power Station, Ardbeg, Rothesay; and on the shore south side of Stravannan Bay. Only one dyke of the Brunton type occurs in the Great Cumbrae, a north-west dyke, 11 feet thick, at Portachur Point.

Olivine Tholeiite.—These dykes appear to represent a further and more basic stage than those of the Brunton type, although preserving a sufficient community of character with the foregoing to warrant the view that they are a continuation of the same series. They are characterized by the presence, often an abundance, of fresh olivine, and by the presence of a glassy base in minimum quantity. No chemical analysis of this group has yet been made. Two types are recognized according to the relative abundance of olivine. The first type, characterized by a small quantity of olivine and by its restriction to the groundmass, is represented by a large group of dykes near Corrie, Arran, and may accordingly be known as olivine tholeiite of the Corrie type. A typical example is provided by a dyke at Birchpoint, on the shore south of Corrie. This rock (Fig. 2*b*) carries numerous small phenocrysts of bytownite-anorthite with narrow labradorite margins. These crystals are often worn and corroded into curiously irregular shapes, and have glassy inclusions arranged in a thick marginal zone which faithfully follows the fantastic outlines of the crystals. The groundmass consists of a diverse mesh of short laths of labradorite (Ab_1 An_1), intermixed with granular or short prismatic crystals of a pale, violet-brown augite which is the most abundant constituent of the groundmass. Minute grains of olivine, partially or wholly serpentinized, and of euhedral magnetite, are uniformly scattered over the field, but form

minor constituents of the groundmass. The interstices are filled by a colourless glass, darkened by innumerable globulites. Quantitatively the glass forms probably less than 10 per cent of the total rock. Minute spherical vesicles filled with dark glass are rather abundant.[1]

Rocks of this type occur freely near Corrie, but have not yet been found elsewhere. They vary within small limits of quantitative relations and texture.

The second type may be known as the Largs type owing to the occurrence of two beautifully fresh dykes on the shore near the town of Largs, Ayrshire. An extended description of these rocks is unnecessary, as they differ from the Corrie type only in the much greater abundance of olivine, not only as granular constituents of the groundmass, but as large phenocrysts. In the groundmass (Fig. 3*a*) there is an augmented proportion of augite relative to the other constituents, and a diminished, almost vanishing, proportion of glassy base. A dyke of this character also occurs in the gorge known as Creag Bhan, Whiting Bay, Arran. This type may be regarded as the most basic of the tholeiitic series of Tertiary dykes.



a *b*

Fig. 3*a*.—Olivine-tholeiite (Largs type), N.N.W. dyke, shore ¾ mile south of Pier, Largs, Ayrshire. × 20. Phenocrysts of anorthite and olivine; groundmass: laths of labradorite, grains of augite and olivine, in scanty base of dark glass. × 20.

,, 3*b*.—Crinanite, N.N.E. dyke, high road above Cordon, Lamlash, Arran. × 20. Ophitic plexus of titanaugite and labradorite laths, with abundant olivine and magnetite. Fresh, colourless analcite in triangular interstices between the felspars.

Ophitic Olivine-Dolerite and Crinanite (Fig. 3*b*).—The dykes of this group stand apart from those belonging to the tholeiite series, and, as far as present knowledge goes, appear to belong to an earlier phase of Tertiary volcanic activity in the Clyde area. A crinanite dyke from Whiting Bay, Arran, was described some years ago (Tyrrell, 1913); but a large number of these dykes have since been

[1] For a figure of this rock see Tyrrell, 1909, Pl. XIX, Fig. 5.

discovered all over the Clyde area. The true crinanites are inseparably associated with, and may be shown to pass into by a graduated series of sections, ophitic olivine-dolerites, which differ from them only in the absence of analcite or radial zeolites. The group is typically non-porphyritic, free from glass, and rich in olivine. In general the rocks are so fresh that it is difficult to believe that the interstitial analcite and zeolites can be other than primary constituents. The crinanites are ophitic olivine-analcite-dolerites of mafelsic composition, i.e. the felspars are quantitatively approximately equal to the combined olivine, augite, and iron-ores. The chemical analysis of a typical crinanite from Inver, Jura (Flett, 1911), gives a norm which falls into the subrang *auvergnose* of the American Quantitative Classification, but very close to *ornose* (III, 5 (3)4. '5). It shows 1·5 per cent of nepheline, and consequently the rock falls into the "unsaturated" group of Shand, whereas the tholeiites are quartzose and fall into the "over-saturated" group.

A typical example from Whiting Bay is described in the above-cited paper. The felspar is much in excess of the augite, so that the small plates of the latter mineral are cut up into thin, detached, triangular strips by the felspar laths. The augite is always the deeply coloured, brown-violet, titaniferous variety. The olivine is generally quite fresh, and occurs in rounded grains which are uniformly distributed over the field. The interstices are filled with analcite or radial zeolites, but the amount is always small, much smaller than in the teschenite group. When the olivine happens to be serpentinized, the green material appears to migrate into the interstices and obscures the presence of analcite. Some of the dykes may thus be set down as olivine-dolerites when they are really crinanites. The rocks vary in coarseness of texture from almost gabbroid to basaltic types, according to the size of the intrusion. They usually occur as broad, massive dykes, which may in some cases have feeder relations to the great crinanite sills of the south of Arran. Besides the Whiting Bay dyke mentioned above, crinanites are now known to occur in Arran at the following places: Kingscross Burn, a quarter of a mile south-west of Kingscross Bridge; by the high road above Cordon, Lamlash (Fig. 3*b*); on the shore south-east of Cordon, Lamlash; the shore a quarter of a mile north of the Pier, Brodick; Invercloy, Brodick; and An Sgriob Quarry, 2 miles south of Corrie. Related olivine-dolerites occur at the first fall in Glen Ashdale, Whiting Bay, and on the shore near Dunfion, Corriegills.

In Bute a N.-S. crinanite dyke extraordinarily rich in fresh olivine occurs on the road 2 miles north-east of Dunstrone; and a 3 ft. N.N.E. dyke on the shore at Kerrytonlia is probably also a crinanite, but contains much diffused serpentinous matter. The related olivine-dolerites also appear in several places. In the great Cumbrae two crinanite dykes are known, and two of the related olivine-dolerites (Tyrrell, 1917). Both here and in Bute the dykes of this group trend in a N. to S. or N.N.E. direction. On the Ayrshire mainland crinanites are known from the shore near the Heads of Ayr.

Conclusion. — Although much still remains to be discovered

concerning the thousands of Tertiary dykes in the Clyde area it is already clear that they show considerable petrographic diversity, and that the various groups have differing relations in regard to their size, length, direction, age, and degree of connexion with the local centres of Tertiary volcanic activity. Only rocks of andesitic or basaltic composition have been dealt with in this paper. There is a well-marked division into two groups: (*a*) a tholeiitic group, characterized by the presence of glass, intersertal texture, phenocrysts of basic felspar, and presence of occult quartz; and (*b*) a crinanite–olivine-dolerite group, with coarse ophitic texture, with interstitial analcite or radial zeolites, rich in olivine, and free from glass or phenocrysts. The tholeiitic group ranges in chemical composition from sub-acid types (Anderson & Radley, 1916, p. 210) to thoroughly basic types such as those of Corrie and Largs. The crinanite–olivine-dolerite group, however, shows no significant variation, and remains uniformly basic. It is probable that other groups will be found as investigation proceeds, especially in Arran, where only a tithe of the dykes (and related sills) have been closely examined. It will be necessary in future to define the relation, if any, between the great pitchstone-felsite group of Arran and the tholeiitic series. There may also be a relation between the crinanites and the basalt-felsite composite sills and dykes of the south of Arran.

I must acknowledge with gratitude the assistance received in this work from Dr. H. H. Thomas, Petrographer to the Geological Survey, who has not only loaned to me all the Survey slides bearing on the subject, but has looked through many of my slides and compared the rocks with the types occurring in Mull. I am also much indebted to Mr. Chetai Yu and Dr. Alex. Scott for the excellent chemical analysis of cumbraite in this paper.

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IV.—Observations on the Reconstructed Skeleton of the Dinosaurian Reptile *Diplodocus Carnegiei* as set up by Dr. W. J. Holland in the Natural History Museum in London, and an attempt to restore it by means of a Model.

(PLATES XXII AND XXIII.)

By the Rev. H. N. HUTCHINSON, M.A., F.R.G.S., F.G.S., F.Z.S., etc.

IN the following pages the writer has endeavoured to consider this skeleton in a common-sense way, and to arrange the limbs with reference to ordinary mechanical principles, and also by comparison of the bones with those of different mammalian and reptilian types. A good many years ago, Von Meyer was so struck by the colossal and rather straight hind-limb bones of the Dinosauria and their superficial resemblance to those of elephants, that he proposed the term Elephantopoda; but at that time the group had not been classified by Marsh and others into distinct sub-orders, with very different limbs.

The writer maintains that Dr. W. J. Holland,[1] Professor Osborn,[2] Dr. Marsh, Hatcher,[3] and others who are responsible for the present reconstruction (see Plate XXII) have been, perhaps unconsciously, influenced by Von Meyer's interpretation, and consequently were somewhat too anxious to produce something very big and imposing. He has endeavoured to give a more natural interpretation of this skeleton, and to bring it more into harmony with other types of reptiles. The restorations by Tornier and Holland are given in the *American Naturalist*, vol. xliv, 1910.

Before proceeding to discuss the details of this colossal skeleton, 81 feet long or more, it will be convenient briefly to summarize the broad conclusions which have been arrived at.

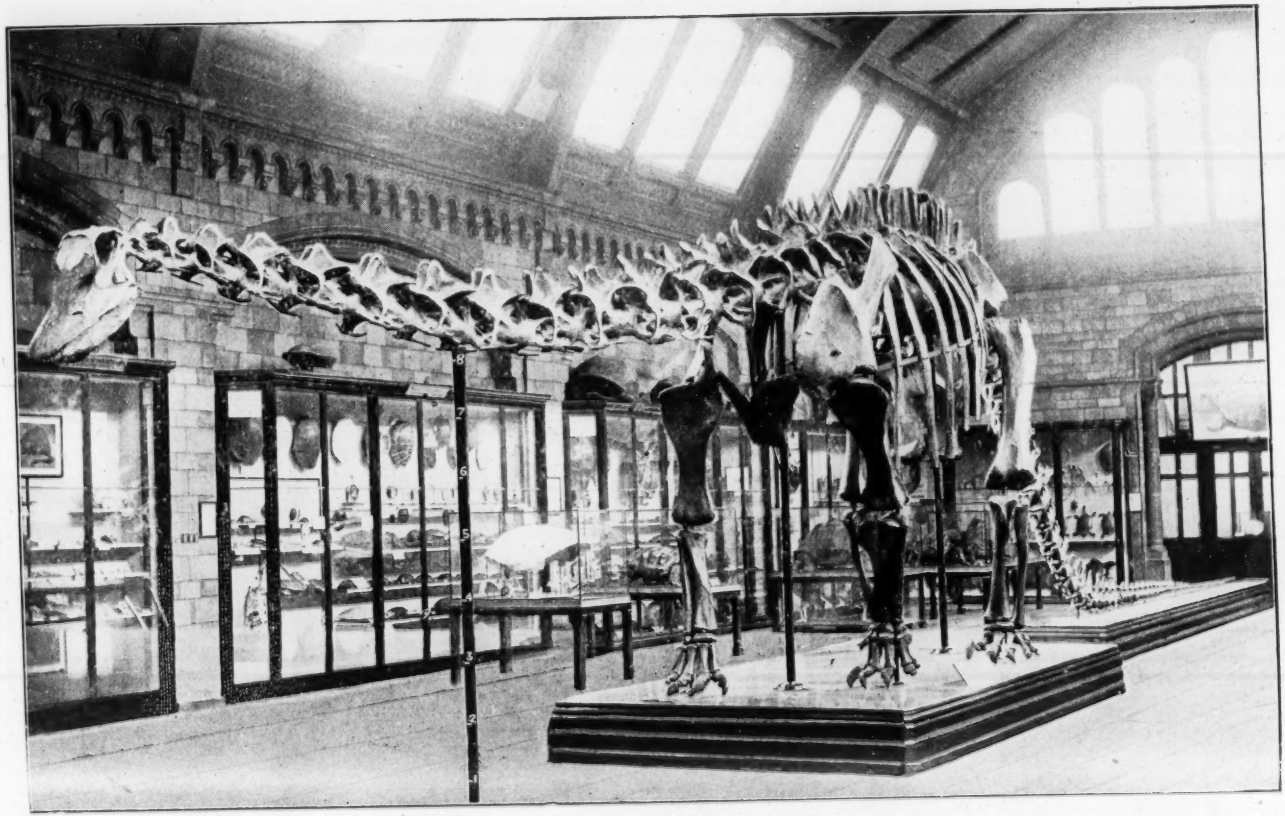
1. With regard to the general pose of the skeleton. There are grave reasons for considering that it stands too high.

2. The limbs, instead of being placed in a vertical plane, should be inclined at an angle to the body, somewhat as we see in lizards and crocodiles. Such an arrangement involves bringing down the vertebral column into a lower position, such that the

[1] W. J. Holland, Memoirs of the Carnegie Museum, vol. ii, No. 6, *The Osteology of Diplodocus, Marsh.*

[2] "A Review of some recent criticisms of the restorations of Sauropod Dinosaurs existing in the Museums of the United States, with special reference to that of *Diplodocus Carnegiei* in the Carnegie Museum": *American Naturalist*, vol. xliv, May, 1910.

[3] Dr. J. B. Hatcher, Memoirs of the Carnegie Museum, vols. i and ii.



Model of the skeleton of *DIPLODOCUS CARNEGIEI*, set up under direction of Dr. W. J. Holland, of the Carnegie Museum, Pittsburgh, Pennsylvania, U.S., in the British Museum (Natural History).

abdominal surface will rest not very far above the ground. The writer has constructed a model 4 feet long in plasticine. Plate XXIII is from a photograph of a plaster cast from this model, which may now be seen in the British Museum (Natural History), Cromwell Road, S.W. It is in the Reptile Room and under the *Diplodocus* Skeleton.

3. That *Diplodocus* was, in habit, partly aquatic and partly terrestrial.

From Plate XXIII the reader will see the position that has been chosen for this restoration. The tail mostly rests on the ground and the body is horizontal, while the long neck has a slight and graceful curve upward. A long, narrow ridge is shown on the back, which gradually rises upward from the shoulders to the lumbar region. The writer thinks he is justified in making this ridge, because a ridge exists in many recent reptilian types, though of course such appendages depend largely upon climate, etc. Lizards inhabiting sandy deserts show a profusion of spines, scales, etc., which evidently are protective. Even plants show a similar tendency to avoid the chances of being devoured by hungry mammals. But we must not assume such conditions existed, and so have dispensed with all appendages of that kind.

The limbs should be quite free from the body; and any attempt to place the femur within the body of *Diplodocus* as if it were a mammal would be a fatal mistake. Dr. W. J. Holland has ventured to do so (see his restored skeleton in the Natural History Museum and Plate XXII).

But such interpretation is not borne out by the shape and general plan of the femur. The writer contends that to place the limb bones in an upright position, as in the skeleton now under consideration (and in the restorations of Marsh, Hatcher, Osborn, and others), is not consistent with the position of *Diplodocus* in the animal kingdom. For, after all, it is a reptile. There is no getting away from that fact: and therefore we must beware of the temptation to give any appearance of usurping characters that properly belong to the mammalian class. But on the other hand, to say that it is a reptile does not necessarily imply a belief that it crawled low down like a lizard or a crocodile. The somewhat grotesque arrangement of the skeleton shown in Dr. Tornier's restoration is based on that view, and the result is obviously an impossible interpretation. Nor can the writer see his way to accept the view that *Diplodocus* walked in the sense in which we apply that expression as to the mode of progression seen in big mammals such as the elephant and rhinoceros.

According to Von Zittel, the Sauropoda display closer relationships with Crocodilians than do the other orders of Dinosaurs, and share a number of features in common with the Parasuchia (*Belodon*, etc.). This important conclusion by such an authority must be borne in mind in considering *Diplodocus*. Hence the writer feels justified in dealing with the femur of *Diplodocus*, largely by comparison with that of the crocodile.

We must try to picture something between crawling and walking, as expressed by our restored model. The relatively small size of the pelvic girdle is, of itself, enough to remind us that, in trying to

form a mental picture of *Diplodocus* as it lived, we must constantly bear in mind that it belongs to a rather generalized sub-order of the Dinosauria, and that among recent reptiles the Crocodile is the nearest thing to it.

With regard to the extremities of the limbs, the hind foot and manus have been given positions which may be described as plantigrade on the whole, but not so much so as the crocodile or the lizard.

The photograph of the model seen in Plate XXIII will serve to show that the writer has endeavoured to steer a middle course between the extreme view of Dr. J. B. Hatcher on the one hand and Dr. Tornier on the other (see Fig. 2).

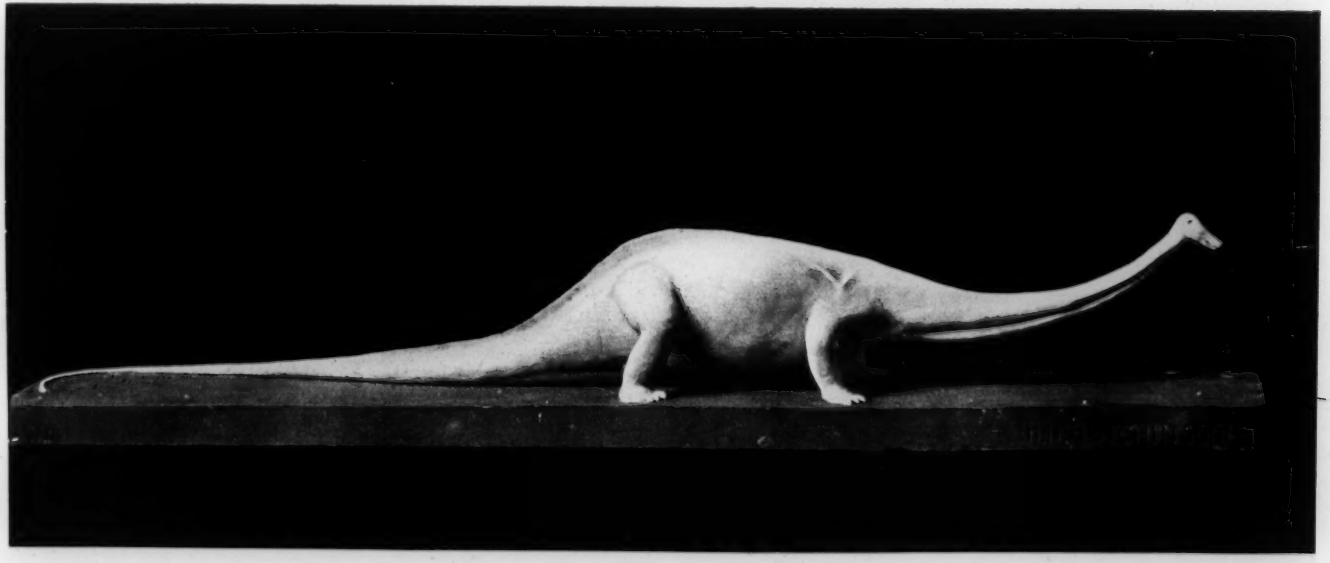
Habits.

With regard to the habits of this creature, there have been great differences of opinion. The late Dr. J. B. Hatcher, whose valuable papers on this subject the writer has read with great interest, was at first inclined to believe that *Diplodocus* was an aquatic reptile, but subsequently he somewhat modified his views, and in his latest paper (Memoirs of the Carnegie Museum, vol. ii) he gives reasons for thinking that the habits of the creature were mainly terrestrial. The present writer is not inclined to adopt this view, but considers that *Diplodocus* spent much time in the waters of the rivers and lakes in those far-off Jurassic times.

To take one reason only, it is difficult to imagine this great creature supporting such a long neck and a still longer tail on dry ground. When standing up the strain of supporting so much weight might become too excessive, but by taking to the water and resting there such strain would be greatly relieved. Perhaps the shape of the jaws and of the proximal end of the skull, which is decidedly duck-like, helps to confirm this view. The swan has a long neck, but gets over the difficulty by keeping it upright. This no doubt suggested the attitude given in Dr. Tornier's restoration of the skeleton.

At first sight *Diplodocus* might possibly appear a somewhat defenceless kind of animal, but judging from the habits of certain living reptiles, such as the monitors, one may safely conclude that this long tail was used very effectively as a whip whereby to lash its enemies. Its great length is remarkable. The long neck doubtless made a long tail desirable, otherwise *Diplodocus* could not succeed in hitting an enemy trying to attack its head.

Professor H. F. Osborn in his paper on "A Skeleton of *Diplodocus*" (on p. 14) leans to the view that *Diplodocus* was of aquatic habits, holding that the tail was especially modified to function as a swimming organ, and was provided distally with a vertical fin. He believes the chief function of the tail to have been that of a propeller to aid the animal in swimming, and that it functioned secondarily as a balancing and supporting organ. While holding that the Sauropoda are aquatic and quadrupedal, he infers that they were capable of migration on land and assuming both a bipedal and tripodal position, the tail when in the latter position functioning as a third support in conjunction with the hinder pair of legs.



Photograph of Model of *DIPLODOCUS CARNEGIEI*, as restored by the Rev. H. N. Hutchinson, M.A., F.G.S., F.Z.S.

It may be worth while briefly to indicate the views put forward by Dr. J. B. Hatcher, O. C. Marsh, and Professor H. F. Osborn. As Hatcher points out in his valuable paper above referred to, Marsh was the first to advance the aquatic habits of *Diplodocus*, having considered the position of the narial openings (nostrils) quite on the top of the skull, as suggestive of such habits. But this conclusion, some authorities think, is more or less shaken by the fact that certain mammals show rather similar conditions without being aquatic. Again, in dealing with the skeleton of *Cetiosaurus*, he lays stress on the open cancellous tissue of the vertebræ and limbs. At the time it was thought that they showed no trace of any medullary cavity. But more recent researches have shown that some of the Sauropoda *had* a medullary cavity. Dr. Hatcher thought that, if modified at all for aquatic habits, it was in the direction of more open and cancellous tissue, even than that which obtains in the Cetacea, and calculated not only to give greater buoyancy to these massive quadrupeds when in the water, but in addition to give the greatest possible surface for muscular attachment compatible with the required rigidity and with the least possible weight.

In the same paper Hatcher sums up his conclusions with regard to the locomotive powers of *Diplodocus* in the following words: "That the movements of the animal when on land were decidedly slow and clumsy; for, had *Diplodocus* and its ancestors been addicted to terrestrial life, the habitual support of so massive a body in so light a medium as the atmosphere would scarcely have failed to produce closely applied and well-finished articular surfaces to the limb-bones similar to those which obtain in such members of the Theropoda as are of undoubted terrestrial habits."

In his second paper (Mem. Carnegie Inst., vol. ii, p. 58) Hatcher revises his previous conclusions. He disagrees with Osborn's conclusion about a tail-fin. The limbs, he thought, were essentially terrestrial. They are not abbreviated or subordinated, as in the Amphibia and Reptilia and some aquatic Mammals. So he thinks the limbs were first of all ambulatory to give support to the body. He also believes his conclusions to be strengthened by a study of the fossil remains found with *Diplodocus* and the nature of the rocks in which they occur, viz. sandstones. Thus we see how the various authorities differ among themselves. One more argument may be mentioned here. He refers to the deeply pitted articular surfaces of the various parts of the appendicular skeleton (i.e. the four limbs and the pectoral and pelvic girdles). These, he thinks, may mean that there were thick cartilaginous pads interposed between such surfaces at the various joints of the limbs and feet. This want of closely-fitting and well-defined articular surfaces would appear to afford additional evidence of aquatic habits. Here the writer would like to point out that an animal may be very largely aquatic in habit without showing much trace of such habit in its skeleton. For instance, the hippopotamus, the water-rat, water-hog, otter, polar bear, and crocodile are largely aquatic, and yet if known only by fossil remains, would be put down as entirely terrestrial! One has to be cautious in drawing conclusions. American naturalists have

pointed out the compressed shape of the body, like that of a herring, as confirming the evidence of aquatic habits (see Fig. 1).

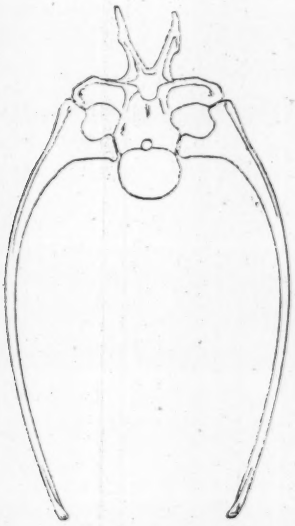


FIG. 1.—Ribs of *Diplodocus* in position.

HISTORY OF THE SKELETON.

We must now consider the skeleton in detail. In dealing with this skeleton, it must be remembered that we have before us not the actual skeleton, but a reconstruction thereof. Each bone, as we see it, is a cast made from a model, and these models are based on several finds of *Diplodocus* made at different times by Marsh, Osborn, Holland, and others.

MATERIALS FOR THE RECONSTRUCTED SKELETON.

Before we proceed to discuss this reconstructed skeleton, it will be convenient to indicate very briefly the nature of the fossilized material on which it is based. Dr. J. B. Hatcher explains in his two valuable papers, (1) Mem. Carnegie Museum, vol. i, p. 4, (2) Mem. Carnegie Museum, vol. ii, p. 58, that his illustration of the skeleton, as far as he knew it then, was based on two skeletons neither of which was complete: (1) that known as No. 84, collected by Dr. J. L. Wortman in the expedition of 1899, and (2) another collected by D. A. Peterson in the expedition of 1900, in the same quarry in Sheep Creek in Albany, County Wyoming.

From a paper by Dr. W. J. Holland (Mem. Carnegie Museum, vol. ii, p. 225), we learn that since Dr. Hatcher's papers were published two other imperfect skeletons have been found. Apparently the skeleton set up in London may be taken in a general way to correspond with the drawing in Dr. W. J. Holland's memoir already referred to.

With regard to skulls of *Diplodocus*, Marsh had only two. The Carnegie Museum has a skull, but no complete skull is yet known. We have to be content with the photographs, etc., in the paper by Dr. W. J. Holland already referred to. The restored skull in the reconstructed skeleton in the Natural History Museum is based on these two skulls, but it probably will be modified when other specimens are discovered. The vertebral formula seems to be:—Cervicals 15, dorsals 11, sacrals 4 (or 5), caudals 35 (or 34).

The Posterior Limbs.

We must pass on now to consider the hind-limbs. Let us take, for example, the elephant, and see how its limbs work, comparing it with a lizard, such as *Varanus*. In *Elephas* the femur works up and down in a plane practically parallel with the axis of the body. In consequence a clear space is left for it by the late dorsal ribs, for they rapidly get shorter about midway in the region between the pectoral and the pelvic girdles. Also this enables the elephant to sit down with its hind-limbs tucked away as a horse does. Now *Diplodocus* could not have done this. Fig. 3 (p. 362) shows the

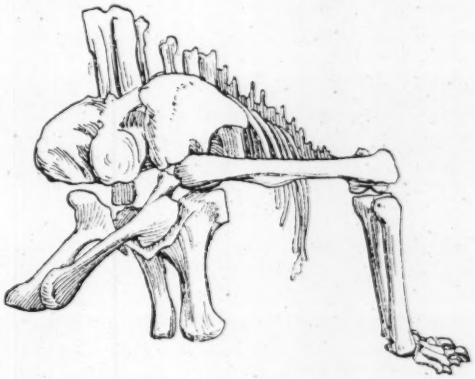


Fig. 2.—Posterior aspect of the pelvis and hind-limb of *Diplodocus* (after Tornier).

position of the hind-limb proposed by the writer. In the case of *Varanus*, a lizard, we perceive something quite different; there is not the same clear space for the movements of the femur, for the obvious reason that the femur of the reptile, instead of working up and down in nearly a vertical plane, works in a plane more or less horizontal, which may be compared to the movements of an oar in a rowing boat, while the others might be compared to a pendulum, which swings in a vertical plane. The ribs are shortened only when quite near to the pelvic girdle. The proximal portion of the *Diplodocus* hind-limb evidently was massive, to say the least, and the writer in his restoration (Plate XXIII) has made it fairly big. It may therefore well be asked how can room be found for this mass of flesh attached to the femur and ilium except by putting the limb at an angle with

the body. Again, one feels justified in asking what evidence exists to show that the last two ribs were really as short as those seen in the diagram. Is it not possible that they are only based on guesswork, and made to harmonize with the general conception expressed by the reconstruction ?

FIG. 3.—Hind-limb of *Diplodocus* (after author).

The Femur.—Drawings of the femur of *Diplodocus* are given in Fig. 4. Let us examine these carefully, for it is largely from the

FIG. 4.—Two views of left femur of *Diplodocus*.

nature of this bone that the writer draws some of his chief conclusions. The first point to which we must direct attention is that the head of the femur is very poorly developed, as in the crocodile. Indeed, the femur as a whole is very crocodilian — a fact which some writers seem inclined to ignore. This imperfect head offers confirmation of the writer's view with regard to the arrangement of the hind-limbs. For it seems rather obvious that, if these limbs were intended to be upright and for walking in the manner of an elephant or other large mammal, then we should find this head of the femur much more fully developed—that is, rounder, larger, and more distinct altogether. As it is we see a mere bulging out on one side of the proximal end. How different this to the mammalian femur! But to come back to the Dinosauria, even the huge *Stegosaurus* has a more developed head to the femur. And there is good reason to conclude that this creature used its hind-limbs for walking rather than for crawling, and that they were set at a slight angle to the long axis of the body, as in birds. Again, *Triceratops* (von Zittel, *Palæontology*, ii, p. 243, Engl. ed.) confirms our view; for its femur shows quite a well-formed head, and this Dinosaur was much inclined to a quadrupedal gait. The writer ventures to think that the femur of *Diplodocus* shows a distinct advance upon that seen in *Varanus* or *Crocodilus*. We see the head asserting as it were a kind of individuality. It projects distinctly from the shaft, though only to a slight extent. We might almost be allowed to believe that here Nature was dimly groping after the more perfect types that we see in the Mammalia. We can well believe that this was one reason which led Hatcher and others to place the hind-limb nearly vertical. It is of course most essential that we should know the *true shape* of this bone as well as others. Now the femur we are dealing with is not the actual bone itself, but a reconstruction. The only way to be sure in these matters is to go to the actual fossil bones and see and judge for ourselves what their shapes may be. For this purpose one must go to the Fossil Reptile Gallery of our Natural History Museum. There we see bones and casts of bones of the Sauropoda. There is a femur of *Diplodocus*. It is a good deal crushed, especially at one end. One can compare it with the corresponding bone of *Brontosaurus*, *Cetiosaurus*, and the colossal *Atlantosaurus*. The writer was greatly interested to find that the bone is *distinctly curved* (see Fig. 4*b*). It has a double curvature. This is a very important fact, the meaning of which must be carefully borne in mind when one is attempting to make a restoration of *Diplodocus*. It brings us back to the crocodile, and reminds us that we are far away from the mammalian type. To place such a bone in a nearly vertical plane and so imply that *Diplodocus* was a kind of saurian elephant must be wrong from a mechanical point of view, as well as anatomically! In birds, and in mammals, the head of the femur is well developed; and the acetabulum is so shaped as to conform to this neat spherical head, forming an admirable ball-and-socket joint, a device well-known to the engineer, and well exhibited in man and in birds. But among reptiles this feature is usually absent, being only known among the Chelonia. The femur of the tortoise (or

turtle), however, shows only an imperfect kind of head, not nearly a complete sphere. So with the humerus. Tortoises are highly specialized reptiles; and this contrivance is doubtless a very necessary one on account of the weight of the carapace, for without it the limbs could not perform their proper functions.

Dr. W. J. Holland and some others have been so bold as to place the femur right inside the creature's body, and in that way we presume they attempt to get out of the difficulty above referred to. But the result is certainly strange, causing *Diplodocus* to remind one of a cow rather than a reptile! (see Dr. Holland's model above referred to). Besides, the whole shape of the pelvic girdle militates against any such interpretation. If the femur really worked in the way suggested by Holland and others, the writer believes that a different shape of ilium would be necessary, viz. one more on the lines of a mammal, that is, more outspreading.

It is very instructive to compare the hind-limb of *Diplodocus* and *Triceratops*. Fortunately both these colossal Dinosaurs are exhibited in the same gallery at the Natural History Museum. Consequently the comparison is easily and rapidly made. Now the hind-limb of *Triceratops* (see the writer's *Extinct Monsters* and *Creatures of Other Days*, now in one vol., 1911, p. 182), owing to its rather upright position, and the ponderous nature of this Dinosaur (which probably possessed a heavy dermal armour, at least in the writer's opinion), had to support a great weight. Hence the three ungual phalanges are decidedly broad—more so than in any other known Dinosaur.[1] And, moreover, that outward twist, so noticeable in *Diplodocus*, is entirely absent. These and other features confirm a suggestion of the writer that *Triceratops* may claim to be regarded as a reptile that years ago played the part of a rhinoceros, i.e. foreshadowing in an imperfect reptilian way that great and ferocious mammal! The rather sharp and distinctly claw-like ungual phalanges of *Diplodocus* bear their testimony in favour of the interpretation of the skeleton adopted in this paper; for with the hind-limbs set up in the vertical plane (as in the American reconstruction) (Pl. XXII), the downward pressure brought to bear upon them would be so excessive that they would probably break, or if not, they would be pressed so deep into sand or soft earth as greatly to hinder progression on land. By way of illustration, and to show that this conclusion is based on reasonable grounds, let us take the case of a large dog, say a mastiff. Leave his limbs almost as they are, but give him a heavy body with a great massive vertebra and a long weighty tail; and then endeavour to picture his distress in propelling along the ground this mass of bone and flesh (even allowing for certain corresponding increase in strength of limb)! The weight of his body would be felt as direct downward pressure through the limbs and on to the toes. But place the limbs at an angle to the body, and this great pressure is relieved, because the femur—with the tibia and fibula, with the muscles attached to them—act as a kind of spring, set sideways to the body (see Fig. 3, p. 362).

[1] Compare with foot of *Elephas*.

The Tail.

The writer is convinced that no animal with such a tail as *Diplodocus* possessed could possibly walk along on terra firma with its huge body high above the ground and limbs erect, as in the elephant. And yet such a fact is implied by the skeleton now under consideration. By way of homely illustration, let us try to picture a big Monitor lizard set up on stilts as it were, by giving it long straight limbs, and made to walk with its heavy tail at such an angle as this great *Diplodocus* tail makes with the hind-quarters. Imagination fails! The pull of such a mass of flesh as belongs to the anterior caudal vertebræ would be prodigious! These vertebræ would require to be greatly strengthened by ossified tendons, as in *Iguanodon*. But even there the pull of the tail was lessened by the comparative lightness of the vertebræ.

In all these matters the law of correlation is a useful guide, though we admit by no means an infallible one. In a case like this it seems quite reasonable to make use of this guide, as Cuvier did who first propounded it. Looking at mammalian skeletons generally, we seem to discover that big upright limbs and a proper quadrupedal progression are correlated with small, light tails, as in *Elephas*, *Bos*, etc. Why is this? The answer seems to be, first, that the drag of a heavy tail would be too great, and secondly, that the limbs are designed for rapid movement. Let us inquire whether such a deduction is confirmed by any extinct reptile.

We return once more to the Dinosaur, which more than any other approaches the heavy type of herbivorous mammals; and that is the very remarkable *Triceratops* which bears out in a wonderful way Cuvier's prophetic vision of a "great herbivorous reptile" as applied to the famous *Iguanodon*. A glance at the model skeleton at South Kensington with its huge hind-limbs shows that, instead of making an angle with the body, they moved up and down in a vertical plane, as in *Elephas*, *Bos*, etc., or a very nearly vertical one. So here we actually have before us a reptile walking, as far as the hind-limbs are concerned, after the manner of an ox! Its toes point forwards; and it evidently walked in true quadrupedal fashion, though perhaps they may have had a slight inclination outwards, as in birds. And what about its tail? The tail is comparatively light and slender, and quite unlike that of any other Dinosaur. And so our argument is confirmed; *Diplodocus* never had its femur working in a plane parallel to axis of the body as in mammals.

Discovery of a yet Greater Reptile.

Some five or six years ago, news was received of the discovery in German East Africa of Dinosaurian bones, of the sub-order Sauropoda, exceeding in length anything yet known even in the Western States. Wonders never cease in the domain of palæontology. Here were bones of such colossal dimensions as would have fairly staggered even the late Professor Marsh! North America no longer can claim the biggest reptile that ever walked the earth. East Africa takes the palm. For here are bones which afford a basis of comparison of relative sizes, and one authority has ventured to estimate the length

of this new reptile, *Gigantosaurus* by name, at 150 feet! This discovery, we think, tends to confirm the above argument with regard to *Diplodocus*, its tail and its general pose; for the larger the reptile the greater the pull of its tail on the pelvic region, to say nothing of the strain on the legs. Besides, mathematicians now tell us plainly that there are certain physical limitations to the size of a terrestrial animal (see recent discussions in *Nature*).

By articulating limbs vertically, Hatcher and others have made a kind of mongrel animal, part reptile, part mammal. *Nature does not mix her types*; so *Diplodocus must* be either reptilian or mammalian; it cannot be both. Its upright limbs are an anomaly. Mammals are swifter of foot than reptiles. The mammalian skeleton is constructed for speed, and is in every way adapted for upright limbs. The pectoral and pelvic girdles are adapted to such limbs. This is seen most conspicuously in the humerus and the femur.

Articulation of the Vertebral Column.

A few years ago the writer, in a visit to the Berlin Natur-Kund Museum, had the opportunity of discussing the *Diplodocus* skeleton with Dr. Brauer of that Museum. He is among those who do not accept the interpretation of *Diplodocus* as represented by the skeleton in London. And with regard to the tail, he brought forward an argument which, as far as the writer is aware, has not been satisfactorily answered. It is this: that several of the early caudal vertebræ have been forced into unnatural positions, as shown by the curious angular gaps between them. This can be distinctly seen in the London specimen. But in the restored skeleton of Dr. W. J. Holland's Memoir on the Osteology of *Diplodocus*, Marsh (Memoirs Carnegie Museum, vol. ii, No. 6), there is no sign of this want of harmony in the arrangement of the caudal vertebræ.

The present writer has also noticed that a good many of the vertebræ a little below those just spoken of show an entire want of contact between the surfaces of the pre- and post-zygapophyses. One would think that facts such as these might be sufficient in the minds of unprejudiced naturalists to settle the question of the slope of the tail, etc. But no! the American palæontologists wished this great reptile to be as tall as they could make it. It has been shrewdly pointed out by Professor S. W. Williston of Chicago, that in *Diplodocus*, as set up in our Natural History Museum, the position of the tail is such as to make the extrusion of an egg an impossibility! It is not easy to conjecture what answer will be made to this objection by other Transatlantic naturalists.

Supposing, as is likely, that *Diplodocus* was partly aquatic in habit and sought his food in the waters of rivers and lakes, one can well imagine that such a long tail would be useful by way of balancing the body, and especially so if at times the body was raised up to bring the head and neck up to the surface of the waters for respiration. Professor H. F. Osborn put forward this view in 1899 (*Science*, n.s., vol. x, No. 259, pp. 870–4, December 15, 1899).

But he evidently stretches this view too far in the sketch of a model of *Diplodocus* standing on its hind-legs, published in the

Century Magazine, September, 1904. In the former one can see clearly that Professor Osborn has disregarded the true proportions of *Diplodocus*, making the neck far too long, the fore-limbs too small, and giving it a very weak chest!

The Carpal and Tarsal Bones.

If *Diplodocus* walked as a mammal, then we can only say that its walking must have been of a very inefficient character. Have the American naturalists ever considered this point—that *Diplodocus* seems to possess very few wrist and ankle bones? They were evidently largely encased in cartilage, as in living reptiles and in all the early amphibians and reptiles. *This, we maintain, renders it quite impossible for the animal in question to have walked like an elephant.* More bones would be required in the joints to give the necessary strength to bear so great a weight, and also to render them sufficiently flexible their surfaces would not have been so flat. On comparing the carpals and tarsals with those of living reptiles, the writer finds that they approach more nearly to those of the Brazilian tortoise than to anything else. In the hind-limb there is the same fusion of several bones into one, thus forming a single bone which probably consisted of the fibiale, intermedium, centrale, and tibiale; in the carpus, we seem to have the radiale and centrale combined and perhaps the intermedium. Now, if these bones so much resemble the corresponding bones of a tortoise, is it not allowable and reasonable to argue that the limbs were used in the same manner, and especially that the joints were not subjected to such extensive or so frequent flexure as in the case of an elephant? Consider how widely the mode of progression of a tortoise differs from that of a mammal. The former slowly drags the limb round much as an oarsman might slowly bring his oar forward for the next stroke, while the elephant quickly brings it forward much as a man brings his leg up for the next stride, and in so doing he bends the tarsal bones in a way that is not possible to any reptile.

But, after all, the writer would urge that perhaps the best evidence for the view here maintained is to be found in the nature of the pelvic girdle. It is beyond all doubt crocodilian, and well adapted to hold the kind of muscles required to work the hind-leg sideways like the oar of a boat. It certainly does not possess that arching-over shape necessary in the case of an animal that uses its hind-leg for movements up and down like a pendulum (see p. 362, Fig. 3). There simply is no room for the big muscles that would be required for that kind of movement.

The Fore-limbs. (Figs. 5–7.)

The writer has long maintained that the worst of all mistakes made in the setting up of the skeleton now under consideration is the way in which the *fore-limbs* are set up. It is hardly too much to say that, in the whole animal kingdom, there is not to be found any limb arranged in such a weird manner as this! Taking a side view of the skeleton, one sees with positive amazement that the bones make an

inward curve, like a bow set up, so that its convex side points towards the posterior end of the animal. Fig. 5 shows the articulation proposed by the writer.

The position of the fore-limb is mechanically impossible! Such a bow would collapse under the strain put upon it.

It is important to bear in mind that this curvature is all in one plane, a vertical plane. There is no foreshortening or any bulging out at an angle to the body as in modern reptiles. Now this must be wrong. We will return to this matter later on. It is difficult, one might almost say impossible, to conceive that such a bone was intended to be used for movements in a direction *AB* and *CD* parallel with the major axis of the skeleton, as in mammals, as indicated in the diagram Fig. 8, p. 369.

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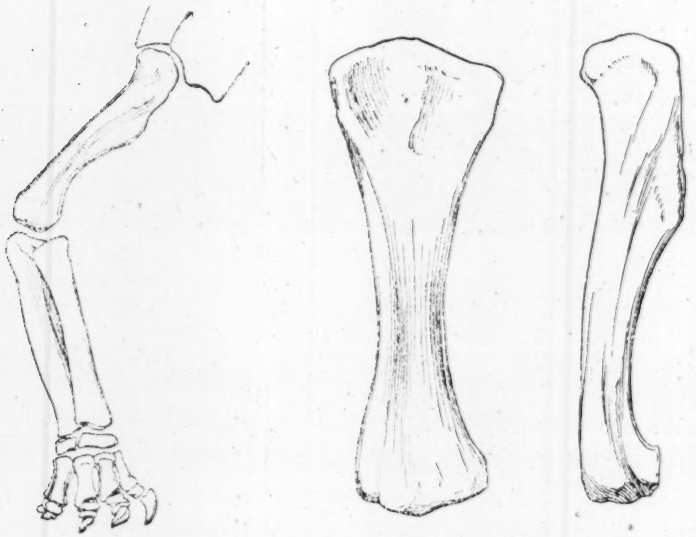
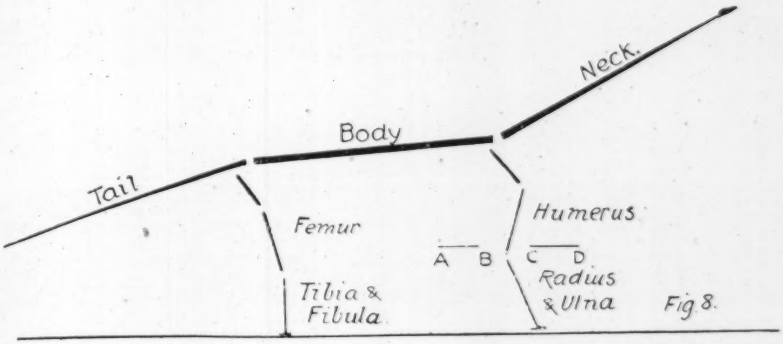


Fig. 5, fore-limb (after author); Figs. 6, 7, two views of humerus of *Diplodocus*.

As already pointed out, that inward curve of the humerus makes it weak. Hatcher put it the other way about. But no bone intended to work in such a manner would be so thin in the direction at right angles to its movements. They are always thick in the direction in which they are used. It must be wrong mechanically. Compare the humerus of a dog, or rhinoceros, elephant, etc. They all have a rounder shape which gives them the necessary strength for movements in the directions *AB* and *CD* in a vertical plane, or, in other words, in directions at right angles to its major axis. Now this is just the direction in which the humerus is thinnest.

Now compare this arrangement with the posture adopted in our restoration. The humerus now works something like an oar. Fig. 9

shows how on the reptilian plan the movements of humerus would follow the arc *ABC*, and in this way the great breadth of this bone would make it thick, or deep, just in the direction where strength is required. Again, that broad spatulate end shown in Fig. 21 is really another argument in the same direction. Looked at from a mechanical point of view, it speaks volumes. Why should it have that large rounded end unless its surface moved more or less in an arc and attached rather loosely to this concavity? Moreover, the glenoid cavity, although not very well preserved, seems to exhibit a shape more or less corresponding with such an outline (Figs. 20–3). The crocodile's humerus is useful for comparison.



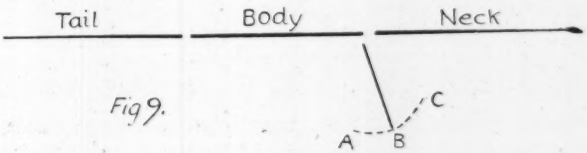


FIG. 8.—Diagram to illustrate wrong articulation of the limb-bones of the *Diplodocus* skeleton. The body, neck, and tail are shortened for convenience.

FIG. 9.—Diagram showing working of humerus of *Diplodocus* (ground-plan).

As mounted, this broad, spoon-shaped blade (see Fig. 6) is placed directly at right angles to the scapula and general direction of the glenoid cavity. Is it likely the big muscles attached to this broad scapula could suddenly change their direction, and somehow twist themselves on to the humerus? They would have to pass over a long and rather sharp ridge. And, moreover, the surface of contact is so small as to suggest a mere point of contact and not a proper broad surface. Such a condition is absurd and unthinkable. Bear in mind that owing to the great weight of *Diplodocus* the pressure on this ridge would be tremendous. The muscles would be lacerated and after a time actually severed. But on the other hand, by turning humerus round 90 degrees we get a suitable broad surface to which the muscles can be attached without violently changing their direction.

This can best be illustrated by means of a pocket-handkerchief. Place it on an extended left arm, with part hanging over one side near the body. Then put the right hand under it with the fingers placed at right angles to the arm. They project in a sharp edge. Now turn the hand round through 90 degrees of arc, and this awkward projecting edge vanishes. It is most instructive to compare with this the articulation seen in *Nesiosaurus*, *Pareiasaurus*, *Iguanodon*, *Thescelosaurus*, and many other forms. They all confirm the idea of an oar, rather than a pendulum (see p. 369, Fig. 9, A, B, C).

The writer has consulted on this point a London University Professor of Engineering, who confirms the views here expressed.

Physiology a Useful Guide.

To all students of evolution it is important to bear in mind, as a guiding principle, the one which Sir Richard Owen always kept steadily in view, that anatomy and physiology go hand in hand. There is a kind of correlation between them. The evolutionist, in pondering over the development of animal life on the earth from the earliest geologic periods to the present day, perceives on reflection that every great advance in structure is based not only on anatomical improvements but also on physiological changes. Thus, the mammal takes the place of the reptile in the order of evolution, and exhibits a heart with four chambers, compared with the reptiles' three; and the reason for this is that the mammal is intended to win a higher place for himself. He must be stronger and swifter, and more intelligent than the reptile. His limbs are therefore stronger, and his brain more active. Hence he requires an improved apparatus. Nature, the great designer, acts in much the same way as an engineer. It is as if an engineer had to deal with an old out-of-date motor-car. He wants to improve it and make it run better and faster. So he takes out the old three-cylinder engine and replaces it by one with four cylinders. He also strengthens the chassis here and there, and thus obtains the results that have been slowly arrived at. So nature discarded the old reptilian heart and replaced it by one of greater power to pump the blood to all parts of the body.

Although land mammals differ very much among themselves as regards powers of progression, they are on the whole better endowed for this purpose than either the amphibia or reptilia. This is largely due to their greater activity associated with the relatively more efficient circulatory and respiratory organs. Warm and well-oxygenated blood at a more or less constant temperature circulates freely all over the body, endowing the limbs with considerable power of activity. A like activity either of brain or muscle is not to be expected in the Amphibia or the Reptilia. The skeleton of the mammal is designed with a view to *efficient* walking and running. Now *Diplodocus* being a reptile, we are not entitled to expect that its limbs should be arranged on the mammalian plan. Our study of its limb-bones confirms this anticipation. Its character, we hope, has been vindicated; it no longer can be said to have played a part for which it was not intended by nature.

NOTICES OF MEMOIRS.

I.—British Association for the Advancement of Science.

London, July 6, 1917.

Address to the Conference of Delegates. By John Hopkinson, F.L.S., F.G.S., F.Z.S., Assoc. Inst. C.E., President.

The Work and Aims of our Corresponding Societies.

IT is nearly forty years since I suggested that the Delegates from provincial societies should hold a Conference at each meeting of the British Association, subsequently arranging for the first Conference to be held at Swansea in 1880. Although sanctioned by the Council of the Association it was not an official Conference, being the first of five managed and supported financially by the Delegates only. Having then been in the chair I accept with the greater satisfaction after so many years the honour conferred upon me to preside at the present Conference.

At the Conference held at Swansea in 1880 the following resolution was passed: "That this Conference recommends that at future meetings of the British Association the delegates from the various scientific societies should meet with the view of promoting the best interests of the Association and of the several societies represented." With this end in view it seems to me that Mr. Symons' address was particularly appropriate, for it is surely in the best interests of the Association as well as of its Corresponding Societies that concerted systematic work should be done.

The main object of our Societies is, or should be, to undertake local scientific investigation, and we are here assembled chiefly to discuss the best means of doing so and of obtaining the most valuable results. While all should work to the same end, that end, whatever it may be, can best be achieved by all working in the same manner, or at least on some definite plan, so that the results may be comparable.

It is not, however, to stimulate and direct scientific investigation only that this Conference should aim; there is also for it the wider field of influencing public opinion on the importance of far greater attention than at present being given to scientific education and to many problems concerned with the future welfare of our nation in which science may lend a fostering hand. There is no other country in the world which has nearly so many scientific societies as we have. There are on our list 120 Corresponding Societies (ninety Affiliated and thirty Associated) with an aggregate membership exceeding 46,000, subject to a slight reduction, as some of these societies are represented individually as well as by the Union to which they belong, and some have members who are also members of other societies on our list, but we may, I think, estimate the number of individual members represented as not less than 45,000, while Principal Griffiths, in his address at our Cambridge Conference, in 1904, estimated the total number of scientific societies in the kingdom as about 500 with a membership approaching 100,000. If we could all agree upon some beneficial project what an immense influence we might have! . . .

For Section C, Geology, much good work has been done by the Corresponding Societies, especially for the Committee on Geological Photographs, which was formed by the joint action of the Section and the Conference of Delegates at the Bath meeting in 1888. The photographs (a very large number) are deposited in the Geological Museum in Jermyn Street, where they may be seen; also numerous lantern slides which are lent for lectures. The Committee is still in existence and photographs are acceptable.

Other important geological subjects which have been brought before our Conference are earth-tremors, underground water, and coast-erosion, in the investigation of one or other of which all our Corresponding Societies may help.

The subjects embraced in Section D, Zoology, are by far the most attractive to members of our natural history societies, to whom we owe nearly all our knowledge of the distribution of animal life in the British Isles, far more perhaps of that of the Invertebrata than that of the Vertebrata, about which much was known in very early days. It should be the aim of all such societies to compile and publish lists of the animals inhabiting their areas, recording their localities, carefully noting their habitats, and studying their habits and life-histories. Increasing attention is being paid to our Invertebrate fauna, but there is still very much to be done, especially in the collection and study of the microscopic forms of life in our rivers, lakes, ponds, and ditches, on our stately trees and humble mosses, and even in our soils. Almost every tuft of moist moss teems with animal life which will well repay microscopic examination.

There is another aspect of the subject which has frequently been brought before us, that is the preservation of our native fauna. In endeavouring to prevent the destruction of rare animals or of those approaching extinction all may help. We cannot well make sure of the presence of a rare moth or butterfly without capturing it, but there is never need to take a large series, as is the practice of some entomologists. With birds and mammals it is different; they can mostly be identified by the practised naturalist without shooting them. There are birds, such as the rook and the wood-pigeon, which should be reduced in number, as they are so destructive to our field and garden crops, but such birds as hawks and owls, which are persecuted by gamekeepers, are our farmers' best friends, and their extermination ought not to be allowed. The same may be said of all insectivorous birds. Hawks may occasionally kill a partridge or even a pheasant, the beautiful kingfisher may take a few fish, but the food of the owls, with the exception of a few rare species such as the eagle owl and the snowy owl, consist almost entirely of small rodents.[1] With regard to the species which should be protected, the ornithologists in a natural history society can render County Councils valuable help. An order for the protection of certain birds was

[1] Taken out of a barn-owl's tree at Keswick in Norfolk in April, 1911, were 114 "pellets" containing the skulls of 19 very small rats, 126 long- and short-tailed field-mice, 69 shrews, and 3 small birds (perhaps greenfinches), but no game.

issued by the Hertfordshire County Council in 1895 on the representation of the Hertfordshire Natural History Society, the schedule being drawn up by ornithological members of the Society and accepted by the County Council. . . .

The subject of Museums comes, I think, most appropriately under this Section, for they are of very great educational value. One of the most important committees of the Association was that appointed in 1886, by the co-operation of Sections C and D and the Conference of Delegates, for the purpose of preparing a report on the provincial museums of the United Kingdom. The Committee was very expeditious, thanks to the energy of its Secretary, Mr. F. T. Mott, presenting in the following year a valuable report which appeared in the Report of the Association for 1887 (pp. 97–130) and a further report the next year (Report for 1888, pp. 124–32). In the first report there are tables (I) giving particulars of 211 provincial museums under headings extending across two pages, (II) an approximate estimate of the number of specimens contained in these museums, and (III) a list of collections of special interest indicating the museums in which they are preserved. A large portion of this report is occupied with "Discussion of Details" under thirty-six heads. The second report considers "the ideal to which provincial museums should endeavour to attain", and suggests "practical methods for approaching that ideal". It is not too much to say that these reports are invaluable, not only to those who have the management of museums, but also to all scientific workers who wish to know where, apart from our national museums, the materials for study in their own branch of science are to be found.

The Hertfordshire County Museum at St. Albans—the only one with which I am connected—was not then founded, but I may mention that it is visited largely by children from the Board Schools in the neighbourhood, who take an intelligent interest in the exhibits, quickly find out accessions, and collect and bring to the Curator objects they wish to know the names of, presenting to the Museum any worthy of acceptance. To young children there is one drawback in a museum, which has been felt at St. Albans: they wish to handle the specimens, rightly judging that by so doing they can learn more about them than by merely looking at them. Every museum should, if possible, have duplicates of the commoner objects, accurately named, to lend to schools. . . .

In walking over the Welsh hills I have repeatedly come across roots and stumps of trees in the peat-mosses which frequently cover them; they are evidences of former forests. The land is worthless except for the value of the peat, the removal of which would, for its valuable products, not only as a fuel, well repay the expense, and the ground would be rendered suitable for planting coniferous trees. It is true that most of our peat-covered mountain-land is above the elevation at which it is generally considered that trees will flourish (1,500 feet), but if they did so in the past there seems no reason why they should not do so in the future, for it is far more likely that our climate has become warmer since trees grew on that land than it is that it has become colder. We have also large areas of waste land

at lower elevations, extensive slopes which are too steep for ordinary cultivation between, and on sheep-farms much very poor grazing-land which would be more profitably used in growing timber. As to the best trees to be planted at different elevations and on different soils, at least by private landowners, no doubt there are many botanists in our societies who could greatly help with their advice. In the last half-century we have doubled our imports of timber and now do not produce more than a tenth part of our requirements, although our climate is admirably suited to the production of nearly the whole.

We are far behind most European countries in the relative area of our timbered land. For instance, nearly half the area of Russia and of the Scandinavian countries is wooded, about 26 per cent of the area of Germany, about 17 per cent of that of France, and the same of Belgium, the most densely populated country in Europe until its devastation and depopulation by the Germans, but only about 4 per cent of the area of the United Kingdom, which will probably be reduced owing to the requirements of our war to not more than 2 or 3 per cent.

Next to fostering agriculture let it be your aim, individually as well as collectively in your capacity as members of societies working in harmonious co-operation, to promote to the best of your ability the re-afforestation of our country. By encouraging these two industries you will help to secure its future safety and prosperity.

II.—Report on the Tungsten Deposits of Essexvale, Umzingwane District.[1] By A. E. V. Zealley, A.R.C.S., Geologist to the Southern Rhodesia Geological Survey.

THERE seems to be general opinion that the tungsten deposits at Essexvale consist only of so-called alluvial or rubble wolframite, and that reefs have not been found. This is not true. Some reefs have long been known, and the excavation of the rubble has led to the uncovering of others, which, so far as can be judged without actual sampling and development, offer good prospects for mining. But hitherto there has been a strange reluctance to undertake mining operations on the reefs, whilst the work on the rubble has been largely desultory.

Position.—The known tungsten reefs lie within an east and west rectangular block of country of about 9½ square miles area lying immediately to the north of Essexvale Siding and mainly west of the railway. The reefs extend from the neighbourhood of "The Ranche" (2¾ miles north-west of the Siding) to the Native Church (1½ miles north-east of the Siding). Sixteen distinct reefs are known, eleven of which have had a little work done on them from time to time.

History.—The deposits were first prospected in 1906. In the ensuing two years a fair amount of ore was produced, but in 1909 the production ceased. A little interest was again taken in the deposits in 1912–13, but there was no production in 1914–15. At

[1] Reprinted from the *Bulawayo Chronicle* of May 18, 1917.

the end of that period a local syndicate extensively sampled some thousands of tons of rubble and made trial crushings. The grade was found to be just too low for profitable working by the methods then employed. During 1916, however, determined efforts have been made by other workers to test the rubble of two restricted areas.

Altogether about 85 tons of concentrate valued at £7,165 has been marketed. The returns for 1916 are 2½ tons valued at £467. This was produced by one worker with a few natives in a five-foot rotary diamond washer, and by one man on another claim who hand-picked rubble and recovered 1,600 lb. of wolframite.

The prospecting done on a few reefs that have been opened has nowhere been for more than a few feet below the surface. This may be due chiefly to the fact that the deposit upon which serious prospecting work has been undertaken is from its nature the least likely to prove profitable.

Geology.—The known tungsten-bearing tract of country occupies the central portion of an irregularly oval mass of granite about 8 miles long and 5 miles across at the widest part. The long axis of the mass trends north-west to south-east. This granite body forms the floor of a wide depression which is traversed by two permanently flowing streams, one of which is known as Fern Spruit. The granite appears to pass beneath the surrounding rim of epidiorite and felsite hills. The soil is a pale-red sandy loam. There are very few exposures excepting in the streams and an occasional small but bold granite kopje. The granite almost wherever seen is coarse-textured and massive, that is, not schistose. It is a hornblende granite, and is thus different from the large granite masses of Rhodesia. Patches of epidiorite, probably inclusions of country rock, and dykes and other bodies of felsite are occasionally encountered, particularly near the eastern edge.

The Reefs.—The tungsten reefs consist of *greisen* composed chiefly of a soft greenish-yellow mica or of mica, fluorspar, topaz, and secondary felspar. This rock weathers soft and rusty brown. The greisen has arisen by the action of vapours on a porphyry or aplite (fine-textured white granite free from hornblende and mica). With the greisen of each reef is a variable amount of rather white glassy quartz forming strings or large lenses in the greisen, and evidently connected with the greisenization, that is, deposited at the same time and by the same agency as the mica, fluorspar, topaz, tourmaline, chlorite, wolframite, and scheelite of the greisen.

The constant presence of the quartz lenses as part of the greisen bodies is a great help in recognizing the presence of the greisen. Those parts of the greisen which contain little or no quartz very rarely crop out, and thus may easily escape discovery. No tungsten reefs have been found without the quartz, although it is quite conceivable that such exist.

The quartz strings expand into lenses exceeding 20 feet in width, and thus make low hillocks such as those at "The Ranche" homestead; again two-thirds of a mile to the south-east of this, and at the Native Church a mile and a half north-east of Essexvale Siding.

The reefs vary from 200 yards to about a mile long. The two

most promising reefs exposed are respectively about a mile long and half a mile long so far as proved. These are the Rhoda reef in the north-eastern portion of Plot 27, and the reef running through the Lunar and Moon blocks near the common boundary of Plots 37 and 38.

With one exception the reefs examined strike east to west and dip north at angles varying between 30° and 55°. The reef on Plot 4 strikes north-west to south-east and dips north-east at 53°.

The width of the reefs is of course variable owing to the lenses of quartz. Apart from the quartz lenses, the width averages three feet, and is surprisingly constant.

In each instance the country is coarse massive hornblende granite without signs of shearing or faulting between the reef and the country. It appears, therefore, that the aplite was injected along master joint planes caused by the contraction of the granite on consolidating, and not in fissures caused by faulting. This may have an important bearing on the persistence of the greisen bodies below the surface. In a few instances the mica greisen has a slightly schistose appearance. In a few places greisenization of the country is suspected, but this is on a small scale only, and no tungsten ore has been discovered in it.

With the exception of the Union Jack reef in the north-west corner of Essexvale Reserve the aplite has been completely greisenized so far as can be judged by the small amount of reef exposed. At the Union Jack the intrusion exceeds six feet in width, but about a third of it consists of white aplite apparently ungreisenized.

Stockwork Deposit.—The block upon which most work has been done differs from the above blocks, which may be taken to be normal. The occurrence in question is situated on Tungsten Kopje, a prominent hill of massive hornblende granite with a low ridge extending about 300 yards to the east and a longer one to the west.

The fact that a large amount of float wolframite occurred immediately around the hill led to prospecting on the hill, with the result that a stockwork deposit was discovered extending along the eastern and western ridges and on the north flank of the hill.

Throughout the massive hornblende granite of this zone streaks and seams of aplite containing gashes of quartz are scattered rather sparsely and quite indiscriminately. These seams run in all directions and at all angles, many are nearly flat, but some are vertical; they make small saddles in several places, but pursue irregular courses, and expand and die out quite irregularly. They average a few inches wide and in no instance exceed a foot. None are traceable for more than a few yards. The greisen always carries streaks of quartz and occurs on one or both sides of the latter. The aplite varies in degree of greisenization. In some parts the greisen consists of sugary quartz and pyrite with very fine wolframite scattered through it but invisible to the naked eye. Such a rock weathers brown and strongly resembles sandstone. It is always present in the rotary concentrate. In other parts the greisen consists chiefly of a soft yellow mica.

At the south-west end of this deposit a body of greisen about 6 feet wide, striking north to south and dipping about 40° E., has been opened and afforded rich patches of wolframite.

Minerals of the Greisen.—The minerals detected in the greisens comprise quartz, soft yellow mica, felspar, dark-green chlorite in rosettes, black tourmaline, pyrite (altered to cubes of limonite at the surface), fluorspar (blue, mauve, green, white, and colourless), topaz (pale brown and colourless), galena (rather rarely), pyrrhotite, wolframite, and scheelite.

Small quantities of each of these occur in the quartz. Here and there a bunch or streak of any one of them, including the tungsten minerals, lies in the quartz. The distribution of the minerals in the quartz or in the altered aplite is in fact generally patchy, as is always the case in greisens. Coarse aggregates of any one mineral are occasionally noted; for example, single aggregates of very large wolframite crystals weighing 235 and 157 lb are said to have been found at the stockwork deposit, and similar groups of crystals have been obtained at the Lunar Block (the specimen in the Rhodesia Museum weighing 172 lb. came from here). Pieces of wolframite weighing up to 8 lb. are not uncommon, and groups of pale pinkish scheelite crystals measuring 3 or 4 inches are to be found. The two tungsten minerals are commonly intergrown; but in spite of this and of the fact that scheelite, containing as it frequently does several per cent more tungstic oxide than wolframite, may be worth several pounds sterling per ton more than the wolframite, it was found that the scheelite was neglected by the workers; in fact, considerable trouble was taken by them to separate it from the wolframite and reject it.

Scheelite is a mineral very easily recognized, and the natives engaged in panning the concentrate should be taught to know it. Although it is not unlike quartz so far as colour is concerned—being white, pinkish, or yellowish—its characteristic greasy lustre, softness (it is easily scratched by the knife or by quartz), and heaviness are properties which differentiate it sufficiently from any of the minerals with which it is associated. If boiled in dilute hydrochloric acid it becomes coated with bright yellow powder soluble in alkali.

Among the dark minerals got in the concentrate, magnetite may be recognized (and separated) by the magnet, and limonite by being in brown cubes. Coarse and moderately fine wolframite is easily distinguished from the other black minerals by its greater specific gravity and chocolate-brown streak; it breaks into flat slabby pieces with lamellar structure owing to the presence of a single perfect cleavage; the flat surfaces are bright and shiny (submetallic to resinous lustre), whilst the cross fractures are dull. Ilmenite, which is rather abundant in very fine round grains in the concentrate of the rubble, is difficult to distinguish from fine wolframite by simple tests, and this fact had led to the rejection of the finest concentrate.

Mineralization.—In addition to the minerals common to greisen, the presence both in the stockwork and in the veins, of galena, pyrite, pyrrhotite, and presumably gold, together with the large amount and constant presence of a kind of quartz which is indistinguishable from the ordinary vein quartz of gold deposits, suggests that the Essexvale tungsten deposits are not normal greisens, but to some degree assume the characters of the gold-quartz vein type of

deposit. In fact, they appear to form a connecting link between the two types. This theory is borne out by the character of the mineralization of the country rock alongside the greisen streaks in the stockwork deposit. The rock is pyritized (pyrite and pyrrhotite), and the felspars altered to sericitic aggregates.

The Rubble.—The richer patches of rubble lie within 100 yards of the greisens on the steeper ground and within about 25 yards on the flat ground.

Tests of this rubble indicate that the yield of wolframite (the scheelite as noted above being rejected) varies from 2 to 8 lb. per ton. In this estimate the occasional lumps of coarse wolframite are not included, and fine wolframite and scheelite in lumps of rock and free are also not included, since they are rejected.

In the instance of the western end of the Lunar Block reef it was stated that early in 1916, 1,600 lb. of wolframite was picked up from the surface by hand without any appliances, without even a prospecting pan, notwithstanding that the ground had been broken, turned over, and picked on at least one previous occasion.

Where the rubble is being more thoroughly tested, the ground, made up of angular quartz fragments, brown-weathered greisen, and sandstone-like aplite in a matrix of red loam, is hand-jigged on rocking-screens, the coarse wolframite being hand-picked from the screens. The fines are concentrated in a 5 ft. rotary diamond washer, which recovers the tungsten minerals and even the fine heavy minerals. The concentrate is then panned by hand. The coarse wolframite (pieces over half an inch) are picked by hand and the fines re-panned. Any coarse wolframite with adhering quartz is pestled and panned. The coarse and medium concentrate so obtained is remarkably clean wolframite. The finest concentrate consists of wolframite and scheelite, with a certain amount of quartz, felspar, epidote, hornblende, mica, zircon, and tourmaline, together with a trace of gold, and a fairly large quantity of ilmenite, limonite cubes, and magnetite. The finest concentrate is rejected under existing circumstances, but on a larger scale of operations concentrating tables and magnetite separators may be expected to give profitable results.

REVIEWS.

I.—A Pocket Handbook of Minerals. By G. Montague Butler. Second Edition. pp. x + 311, with 89 figures in the text. New York, John Wiley & Sons; London, Chapman & Hall, Ltd. No date. Price 11*s.* 6*d.* net.

THIS handy little treatise by the Professor of Mineralogy and Petrology in the University of Arizona has met with such a large demand that a second edition has been called for. The original scope and plan proved so satisfactory that no change as regards them was made, and the only difference in this edition is that additions have been made here and there to the original text where experience has suggested the need, and, of course, all typographical errors that have come to light have been corrected.

The mineral species are arranged in the customary order, and are described concisely, but sufficiently fully for the purpose of discrimination. Happy use has been made of heavier type to emphasize the more important or prominent features. Under each we find particulars of the chemical composition, hardness, lustre, colour, streak, cleavage (if any), transparency or opacity, specific gravity, simple blowpipe reactions, and crystal form. We may throw out the suggestion that now that portable, trustworthy refractometers are available, it would be advantageous in a subsequent edition to include details of the refractive indices and of the double refraction where it is present. In the case of a transparent substance a measurement of the refractivity will often settle its identity beyond doubt. The blowpipe reactions are such as can easily be carried out with an ordinary portable outfit. To facilitate the determination of mineral specimens, the more obvious physical characters are tabulated at the end of the book on a series of folded leaves; by consulting this table the inquirer may reduce the number of species to which a particular specimen might belong to two or three, and a reference to the fuller descriptions in the text will lead to the proper identification.

As a help to the prospector Professor Butler in a series of appendices gives the retail prices of good to very fine cut stones, the value of metals and minerals, a glossary of the technical terms and expressions used in the description of minerals, a table of the elements with their symbols and atomic weights, Mohs's scale of hardness, and von Kobell's scale of fusibility. The information given in the first appendix on the charges made by lapidaries for cutting stones is not sufficiently explicit. In the case of "fancy" stones the cost of cutting is based on the weight of the finished stones, whereas for diamonds it is the weight of the rough material that determines the cost, and the charge for faceting a diamond works out at more than fifteen times what it would be for an ordinary stone of similar size when cut. Few lapidaries undertake both classes of work. The author seems to be unaware that the standard weight practically all over the world is the carat of one-fifth gram, and not as defined by him. He points out in a note to the second appendix that the quotations for metals and minerals are those prevailing before the War; inasmuch as the large increases now obtaining will probably in most instances end with it, he has refrained from giving them. The publishers are open to severe criticism for their omission to give any indication of the date of publication; it is only the fact that the author in this note speaks of the "European" war that any clue as to the date is afforded. The curious use of two very different kinds of paper militates against the appearance of the book.

II.—New Species of Fossil Beetles from Florissant, Colorado. By H. F. Wickham. Proc. United States National Museum, 1917, vol. lii, pp. 463–72, pls. xxxvii–ix.

SOME fifteen new species are described and figured under almost as many genera, *Brachyspathus* being new, while all are

comprised in the following families: Carabidæ, Coccinellidæ, Buprestidæ, Sampyridæ, Malachiidæ, Ptinidæ, Spondylidæ, Cerambycidæ, Bruchidæ, Otiorhynchidæ, and Curculionidæ.

III.—The *Zoological Record*, vol. lii, for 1915, has recently appeared and contains as usual papers on fossil as well as recent zoology. The volume for 1916 is in hand, and may be expected this time next year. The book is thinner than usual owing to the dearth of work and the difficulty of obtaining that from enemy countries. It is on sale, in the special parts, at the Zoological Society of London.

IV.—William Smith: his Maps and Memoirs.

THE story of William Smith, "the Father of English Geology" as he was styled by Professor Sedgwick long ago, has been told by his nephew, the late Professor John Phillips, by H. Woodward, Professor J. W. Judd, Mr. Sheppard, and many others (see Geol. Mag., 1869, 1870, 1873, 1877, 1892, 1897, etc.). Mr. Sheppard has recently described his maps (see Proc. Geol. Soc. Lond. in Geol. Mag., July, 1917, pp. 330–1). Now some 200 pages and 17 plates are issued in the Proc. Geol. Soc. Yorkshire for March, 1917. In this elaborate and carefully prepared work, Mr. T. Sheppard presents, in a graphic manner, Smith's career, his special work in Yorkshire, the history of maps, personal memorials, "claims" now first made public, and several of his manuscript memoirs. Besides this the author discusses earlier work on mapping by Owen, Lister, Strachey, Woodward, Desmarest, Pache, Michel, Whitehurst, Smeaton, the Board of Agriculture, Jamieson, Parkinson, and all Smith's maps in detail, so a fairly comprehensive view of this subject is unfolded. The illustrations are admirably selected for their purpose, and the paper (published at 5*s*.) should be in the hands of every geologist.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

June 20, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following communications were read:—

1. "The Pre-Cambrian and Associated Rocks of the District of Mozambique." By Arthur Holmes, A.R.C.S., D.I.C., B.Sc., F.G.S.

Beyond the coastal and volcanic beds of Mozambique (described in a previous contribution—Abs. Proc. Geol. Soc. 1916, No. 994, p. 72) the country assumes the form of a gently undulating plateau, gradually rising towards the west and diversified by innumerable inselberg peaks and abruptly rising clusters of hills. The dominant rock throughout is a grey biotite-gneiss. Interfoliated with this are occasional lenticular masses of hornblende-gneiss and amphibolite, and within these smaller bands of crystalline limestone are sometimes preserved. In many places the gneisses become garnetiferous, while eclogites and basic granulites also occur. Schists—referable to arenaceous sediments—are found only near the coast, where they are

interbanded with gneisses; and, as the latter are mainly of igneous origin, they are thought to be intrusive into, and therefore younger than, the schists. As a general rule, the foliation and the banding of the gneisses are well defined in parallel uncontorted planes, the strike being commonly along, or somewhat north of, a north-east to south-west direction. In certain inselberg peaks, the strike sweeps round the contours, while the foliation surfaces dip quaquaversally from the summit. Into the gneisses later granites, belonging to at least two different periods, have penetrated, riddling them with enormous numbers of small intrusions, lit-par-lit injections, tongues, and apophyses. Rocks of later age are rarely met with; but in a few places dykes of picrite and pyroxenite have been found cutting the youngest pegmatites.

The succession of rocks in eight of the better-known districts is described, and the following general classification is based on the details thus provided:—

Ultrabasic Dykes.	Pyroxenites. Picrite.	Age unknown.
	Intrusive Contact.	
Granites and Coarse Pegmatites.	Biotite-Granites. Graphic Granite and other Pegmatites. Quartz-Veins.	Pre-Cretaceous and Post-Middle Pre-Cambrian.
	Intrusive Contact.	
Granulitic Granites, Pegmatites, and Associated Rocks.	Biotite-Granites (including Porphyritic varieties). Pegmatites and Aplites. Pyroxene-Granite and Quartz. Pyroxene-Diorite Series. Pyroxene-Granulites?	Middle Pre-Cambrian. Pb/U = 0·14–0·17.
	Intrusive Contact.	
Gneisses and Associated Rocks.	Biotite-Gneisses and Gneissose Granites. Hornblende Gneisses. Amphibolites. Garnetiferous Gneisses, Granulites, and Eclogites.	Pb/U = 0·21.
	Intrusive Contact.	Lower Pre-Cambrian.
Crystalline Schists and Limestones.	Quartz-Mica-Schists. Quartz-Magnetite-Schists. Hornblende-Garnet-Schists. Hæmatite-Schists. Forsterite Marbles, and other Crystalline Limestones.	

The above correlations of certain groups of rocks with the Lower and Middle Pre-Cambrian of other regions are based on the determination of lead-uranium ratios of zircons derived from the gneisses and granulitic granites respectively, the zircons having been obtained by crushing and panning the rocks in the field. The gneisses give a ratio of 0·21, comparable with a ratio of 0·24 obtained for Canadian zircons of Laurentian age. The granulitic granites give ratios of 0·14 to 0·17, comparable to those of radio-active

minerals of late Archæan, that is, late Middle Pre-Cambrian, age in Scandinavia (Moss 0·12 to 0·15, Arendal 0·16 to 0·18, and Ytterby 0·15 to 0·17), Canada (Villeneuve, Quebec, 0·17), and India (Singar 0·14).

The rocks are described in detail, with tables giving the quantitative mineral composition and the specific gravities and radium contents. Numerous examples of contact phenomena between crystalline limestones and various types of igneous rock are recorded: pyroxene, amphibole, sphene, and soda-lime felspar being the new minerals chiefly developed, between granite and limestone, with garnet and scapolite in special cases.

With reference to the origin of the crystalline limestones and gneisses the following conclusions are arrived at:—

(*a*) The crystalline schists and limestones are interpreted as arenaceous and calcareous facies of an ancient sedimentary series, their argillaceous complements being unrepresented unless they enter into the composition of the biotite-gneisses.

(*b*) The limestones have controlled the formation of hornblende-gneiss and amphibolite by their interaction with a granitic magma that elsewhere is represented by biotite-gneisses. The cores of the limestones have been enabled to resist further silicification by being thus enclosed within a blanket of rocks impoverished in silica.

(*c*) If the ancient sedimentary series included argillaceous formations, it is thought probable that the gneisses are composite rocks produced by the concordant injection of granitic magma into such formations. This view, although not proved, is supported by mineralogical and radio-active evidence, and by the fact that in certain inselberg peaks the banding of the gneisses gradually dies away as the slopes are ascended, the rocks passing into granulitic granite nearly free from biotite and showing few traces of foliation. These peaks are interpreted as the irruptive foci of granulitic magmas which fed the lateral intrusions represented by the surrounding gneisses.

It is shown that there are at least three types of inselberg peaks that owe their survival to peculiarities of structure and composition. The first type is that just mentioned, in which the foliation is less marked and the biotite content appreciably lower than in the surrounding gneisses. In the second, the peaks are mainly composed of granulitic granite (again poor in biotite compared with the gneisses), and in the third type the peaks are riddled with tongues and apophyses of pegmatite and aplite. In each case the greater resistance offered to denudation is related to the presence of less foliated and more felsic rocks than are found in the adjacent plains. There remains a fourth type—perhaps the most abundant—in which no differences have been recognized. Many of these seem to be isolated relics of gneissic escarpments; and it is suggested that desert erosion, involving the attack of slopes at their base by arid weathering, and the removal of disintegrated material by wind, is the most favourable condition for the development and maintenance of an inselberg landscape. Existing conditions of denudation are considered to be unfavourable to inselberg survival; for the peaks appear to be worn down by the removal of superficial layers by exfoliation more rapidly than the surface of the plateau is lowered.

2. "The Inferior Oolite and Contiguous Deposits of the Crewkerne District (Somerset)." By Linsdall Richardson, F.R.S.E., F.G.S.

In this communication a detailed description is given of the Inferior Oolite of the Crewkerne district.

Roughly speaking, the Upper Liassic Sands to the south-west of a line connecting South Petherton, Crewkerne, and South Perrott, are very similar to their equivalents in the Burton–Bradstock—Beaminster–Broadwindsor district. To the north-west of that line, however, limestones — largely made up of shell-débris—replace a considerable portion of the yellow sands of *moorei* hemera, "thickening" from about 18 feet at North Perrott ("Perrott Stone") to 78 feet at Ham Hill ("Riddings" and Ham Hill Building-Stone).

In the extreme south-western portion of this district, around say Drimpton, the *Aalensis* beds are also probably very similar to their equivalents in the Burton–Bradstock—Beaminster–Broadwindsor district, and at Furzy Knaps, near Seavington St. Mary (4 miles north-west of Crewkerne), what is seen of them is highly fossiliferous. East of Crewkerne, however, these beds "attenuate" and "die out" altogether between North Perrott and Yeovil Junction.

The *Opaliniforme* beds at Broadwindsor, Whaddon Hill, and Chideock Quarry Hill comprise, in descending order—

(*a*) Rusty Bed;
(*b*) Very fossiliferous sandstone; and
(*c*) Sands and sandburrs.

The equivalent of (*b*) is readily recognized at the Cathole Lane Section, Crewkerne, where it is very rich in ammonites. Above it are deposits which are with but little doubt equivalent to the Rusty Bed of more southern localities. East of Crewkerne, the *Opaliniforme* beds—like the *Aalensis* beds — "attenuate," the lower beds apparently disappearing first. They "die out" between East Chinnock and Yeovil Junction.

The *Scissum* beds are 6 ft. 2 in. thick at Broadwindsor, and very fossiliferous. They retain the characters exhibited at Broadwindsor in the area south of the L. & S.W. Railway; but at North Perrott, on the north, what appears to be the equivalent of their lowest portion is softer and thicker. The *Scissum* beds also fail between East Chinnock and the Junction.

The *Scissum* beds are succeeded by the *Ancolioceras* beds—at the Conegar Hill Section, Broadwindsor, two strata, each 1 foot thick. The *Ancolioceras* beds extend into the Crewkerne district: they are well exposed at the Misterton Lime-works and at other sections in the neighbourhood, and apparently were proved in the now filled-up quarry in Haselbury Plucknett village. Probably the *Ancolioceras* beds persist throughout the Crewkerne district.

The upper portion of the *Murchisonæ* beds is the main horizon for *Zeilleria anglica* (Oppel). In the neighbourhood of Beaminster specimens of this Brachiopod are very abundant. The true *Zeilleria anglica* beds are absent from the Conegar Hill Section, but occur at Drimpton, in the extreme south of the Crewkerne district, and apparently were met with at Haselbury Plucknett, east of Crewkerne.